STANDARDIZING THE AMALGAM FILLING

BY

WALTER G. CRANDALL, D.D.S.

SECOND EDITION

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Second Edition

THE enthusiastic reception accorded by the dental profession to the first issue of "Standardizing the Amalgam Filling," adds to our pleasure in presenting the second edition. The need for a simple and comprehensive treatment of the subject of amalgam manipulation has been revealed by this enthusiasm and we believe that a real appreciation of the importance of amalgam restorations, as a factor in conserving the teeth and health of patients, has resulted from this publication.

The present edition of "Standardizing the Amalgam Filling" has been revised in the interest of unity and convenient reference and some of the results of research in metals, made by a highly competent metallographist at Yale, Sheffield Scientific School, have been added. This work, which represents the first intensive use of metallography applied to dental alloys, has been done under the direction of Dr. Crandall and will be reported fully in a later publication.

To those who have gone before us in the investigation of the alloy metals and methods of combining them, we offer our acknowledgments. The best of the past has been combined with research and increased practical experience in the evolution of the Crandall Method of Amalgam Restoration. It is offered to the profession with the assurance that it is founded upon scientific principles and that its application, under varying conditions of practice will result in a step in advance of present methods in the restoration of bicuspid and molar teeth.

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TO the friends and confrères who have assisted me in the experiments necessary to this work, to those who have offered criticism and suggestion, I wish to express my heartfelt and sincere gratitude. The list of those who have disinterestedly aided in this work has grown to such proportions that it seems impossible to particularize here. It is a pleasure to acknowledge my indebtedness to these men and I offer to each and every one my heartiest appreciation.

W. G. CRANDALL.

Standardizing the Amalgam Filling

By Walter G. Crandall, D. D. S.

THE earliest use of amalgam as a material for restoring portions of the human teeth is of comparatively recent date. It is probably well within the past century that it was first employed and within half a century that its use has become at all common. Many men who are still active in the practice of dentistry recall very vividly the contention over the material when its introduction was first becoming general throughout this country as, at that time, amalgam was in such ill repute that its use by any dentist was sufficient to bar him from membership in the dental societies which then existed, and from any association with his confrères.

However, it is not the intent of this article to discuss the amalgam of the past, but the amalgam of the present, and its possibilities. The importance of any material bears a direct relation to the extent of its use. Judged from this standpoint, the importance of amalgam is at once evident, for a comparison of the number of amalgam fillings inserted with all fillings of other materials, when taken from records of actual practice, has always shown at least seventy-five per cent of the total to be amalgam.

In reviewing any scientific research of dental amalgams and amalgam alloys, acknowledgment must be made of the work done in this field by Greene Vardiman Black. If he had given nothing else to the advancement of the dental profession, his name should still be held in grateful remembrance for his investigation and classification of the minute actions of the dental amalgam alloy metals. Two decades have passed and we are only beginning to appreciate the heritage that is ours through his efforts and to realize that we have failed, in some particulars, to take advantage of the work which should have given us an unalterable standard for dental amalgam alloys.

The clinical experience of the past has taught us the value of amalgam and has demonstrated its wonderful tooth-saving qualities, even when it has been used in a careless, indifferent manner. Too often it has been considered only as a cheaper substitute for the patient who can not afford, or will not have, a gold filling, inlay, or crown, and the work has been done with little care in the preparation of the cavity, with a plastic alloy, and without regard to the restoration of anatomical form or occlusion, simply as the quickest means of getting rid of the patient. It is possible, however, to save teeth with amalgam when it has become practically an impossibility to save them with other materials.

Now and then we have all seen cases in which amalgam fillings have given more than ordinary service, proving the inherent value of the material. The more frequent failures show us the lack of a standardized technic for amalgam work. Notwithstanding the more and more frequent discussions of the subject, do we really know the requisite qualities of a dental amalgam alloy; in what proportions it should be combined with mercury; whether or not the cavity should have a cement lining for amalgam; how much force is required to condense amalgam; the form and size of instruments best adapted for this purpose; the modifications of Black's cavity preparation for gold foil which are permissible or advisable for amalgam; the method of alloying which

will produce a dental amalgam alloy with the most desirable qualities?

It is the purpose of this article to bring before you, as plainly and emphatically as possible, the essentials of a standardized technic for amalgam restoration. A clear and systematic presentation of the subject requires the following subdivision into sections:

Essentials of Standardized Amalgam Technic Classified

I. *Proper Cavity Preparation*
II. *Accurately Tested Alloys of the Greatest Strength and Stability*
III. *Correct Amalgamation*
IV. *Correct Instrumentation and Condensation*
V. *Correct Contour and Finish of the Restoration*
VI. *Profitable Fees*

Section I—Cavity Preparation

SCIENTIFIC cavity preparation is as essential for amalgam as for a filling of any other material. Without proper preparation of the cavity, no filling material is given a just opportunity to prove its worth, and the writer is inclined to believe that the lack of such preparation is the most frequent cause of failure of amalgam fillings.

The entire preparation of the cavity should bear a distinct relation to the conditions which surround the tooth. We should study conditions, observe, if possible, the faulty condition which produced the lesion, and attempt to remedy this, producing an environment which will prevent the recurrence of the pathological state. We should study the occlusion and build to withstand its existing force and, if possible, to anticipate future developments. The restoration of a tooth is a surgical procedure and requires expert knowledge in diagnosing and planning. The completed restoration should be fully visualized and decided upon before the operation is begun.

The writer would advise those who wish exhaustive information on the subject of cavity preparation to make a close study of Black's "Operative Dentistry" or to take a course of clinical instruction from some master of Dr. Black's scientific system. It is impossible to consider the subject adequately within the limits of the present article, but we shall consider briefly several forms of cavities occurring most commonly in bicuspid and molar teeth. Its color limits the use of amalgam almost entirely to these teeth.

In the main, cavity preparation for amalgam should be the same as for gold. The ideal cavity is a box form with a flat base and walls at right angles to the base. This, of course, becomes complicated in many forms of cavities, but the principle should be followed in any cavity where stress will be applied to the completed filling.

Dr. Black gives the following as the order of procedure in cavity preparation:

1. Obtain the required outline form.
2. Obtain the required resistance form.
3. Obtain the required retention form.
4. Obtain the required convenience form.
5. Remove any remaining carious dentin.
6. Finish the enamel walls.
7. Make the toilet of the cavity.

We shall consider briefly these various steps, noting especially variations from the usual procedure for gold foil.

1—Outline Form

This form is the outline of the cavity upon the enamel surface; it must be such that it will place all of the margins in areas which are comparatively immune to initial decay.

For cavities on proximal surfaces, the gingival wall of the cavity should be just beneath the free margin of the gum, as decay rarely, if ever, begins at this point when the tissue is in a healthy condition. When the gum has receded upon the root, it will be quite useless, of course, to attempt to place the gingival margin in such an area.

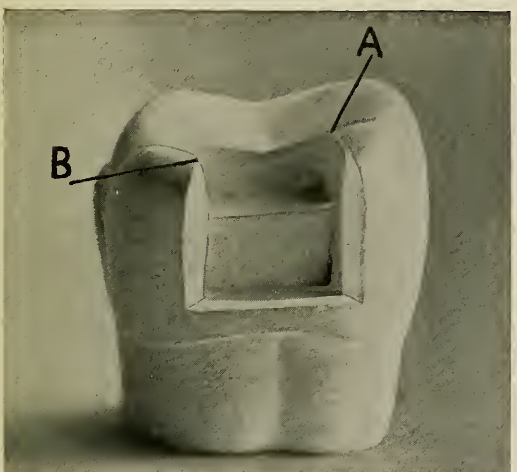


Figure 1 shows an upper molar with cavity preparation for amalgam on the disto-occlusal surfaces. The outline form of this cavity includes all of the area of the distal surface which is susceptible to decay. The buccal and lingual walls are at right angles to the base of the cavity, with flat base on the gingival and pulpal walls.

The buccal and lingual margins must be so placed in the embrasures that food will sweep over and cleanse them, making it impossible for plaques of bacteria to form and institute a new area of decay.

Upon the occlusal surface, under usual conditions, the outline form should include that portion of the occlusal surface which is contiguous to the cavity and should be extended to include all fissures susceptible to future decay.

Where the occlusal and proximal portions of the cavity join, the cavity should be cut as broad as conditions will permit, as shown in Figure 1, A-B. Care should be taken not to approach too near the summit of the cusps, where the enamel rods lie in a direction which will cause inferior margins, and not to cut too deeply into the dentin, as the horns of the pulp often extend to a point where they are easily involved. Especial emphasis should be placed upon the broad outline at this point as the narrow connection between the occlusal and proximal portions of a cavity is a fault common to many operators. The broad outline will give strength to the restoration, where strength is most needed, by allowing a greater bulk of amalgam to be placed at this point. Amalgam is not a ductile material and continued heavy stress upon a small body of it will surely cause it to give way in time; its strength increases rapidly as its bulk increases. We must constantly bear in mind the physical properties of amalgam and adapt our methods to its qualities to obtain permanent results.

If decay has progressed throughout the dentin so that any cusp has become undermined or weakened, the cusp should be cut away, for at least one-third of the occluso-gingival diameter of the tooth, so that it may be restored with a bulk of amalgam. Representative cases in which this has been done are shown in Figures 2, 3, 4 and 5. The wall, in each case, has been

reduced with a stone and beveled so that the reproduction with amalgam will lock the cusp and prevent fracture.

Very often decay has become extensive from both the mesial and distal surfaces and all the cusps are more or less undermined.

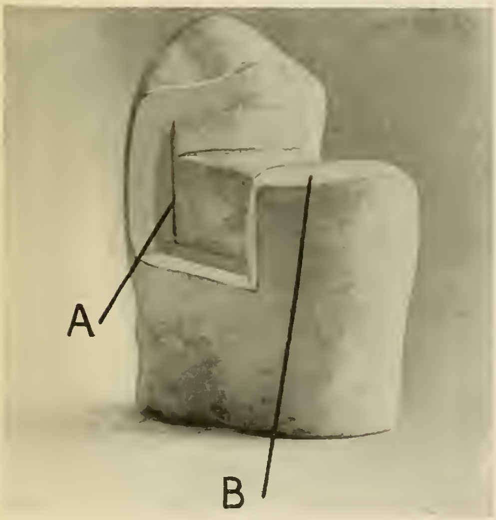


Figure 2 shows a cavity preparation for amalgam in an upper bicuspid. In this case there were extensive cavities upon both the mesial and distal surfaces to such an extent that the lingual cusp had become weakened from loss of normal dentin. The lingual wall at B has been reduced with a stone and beveled so that it may be reproduced with amalgam. This will lock the cusp so that it will not be subject to fracture. The bucco-axial line angle is shown at A. This is part of the resistance form and is an aid in preventing flow of amalgam from the cavity.

Usually teeth in this condition are believed to be impossible to restore, except with a banded crown, but the writer seldom hesitates to restore such teeth with amalgam. Records of these extensive operations, covering a period of years, have yet to reveal the first failure, either from recurrence of decay, fracture, or any other cause. The outline form for such restorations is shown in Figure 5. The gingival walls, A and F, are extended and squared out as they would be for an operation on either the mesial or distal surface. As both the buccal and lingual walls are weakened by extensive decay, they have been reduced so that the amalgam restoration will have sufficient strength to withstand all the forces of mastication.

The outline form of cavities which occur upon the buccal, lingual, and occlusal surfaces is identical with the form which is used in cavity preparation for gold foil.

Adjustment of the Rubber Dam

If the rubber dam has not been adjusted at the beginning of the operation, this should be done, or some other means should be provided to keep the cavity free from moisture, as soon as the outline form is completed. It is not sufficient to prepare the cavity and then dry it, since in this case it will be impossible to remove the debris and the dried salts of the saliva from the cavity and its margins. No moisture should come in contact with the cavity after the final cutting is done.

2 — Resistance Form

The resistance form of the cavity should be the same for amalgam as for gold, that is the cavity should have a flat gingival wall, with definite angles, and a broad, flat step, or pulpal wall. The base of the cavity should be at right angles to the force of occlusion and usually should be at right angles to the long axis of the tooth. This form is illustrated in Figure 1 where the cavity shown has a flat base on the gingival and pulpal walls, with buccal and lingual walls at right angles to the base of the cavity.

3 — Retention Form

The ideal retentive form is a box form, that is a flat base with walls at right angles to the base, as this form gives the greatest strength possible to the lateral walls. If amalgam is properly condensed into a cavity of this kind, it will be retained safely. However, as such ideal cavities are not often presented, we must consider the conditions which actually exist.

As amalgam tends to flow under pressure, it is permissible, in compound cavities, to use more retention than is necessary for gold. This is accomplished by carrying the bucco-axial and linguo-axial line angles, in a very slightly retentive form, to a point near the occlusal surface. This statement is not intended to countenance, in any way, deep or decided undercuts which may weaken the walls and, subsequently, permit fracture. These lines are carried out solely for the purpose of resisting the flow of the amalgam.

Both Figures 2 and 4 show the correct retention form for the bucco-axial line angle at A. A part of the retention form shown in Figure 3 is a small slot, at A, cut in the lingual wall gingivally to lock the amalgam from any tendency to flow distally from the cavity. At B the wall has a bevel which, when covered with amalgam, will overcome any tendency of the wall to fracture.

In cavities like that shown in Figure 5, an extensive resistance surface for the anchorage of the restoration is given by the flat, wide, subpulpal wall. This has been broadened so that only a small amount of dentin remains on either the buccal or lingual wall. As all the force of occlusion is applied to this subpulpal wall, very little anchorage is required. There is a slight undercut at the base of the cavity at C and a bevel from D to E which adds strength. The cusps have been reduced about two-thirds of the depth of the crown to a very safe and immune area. The gingival form, when restored, is anatomic-

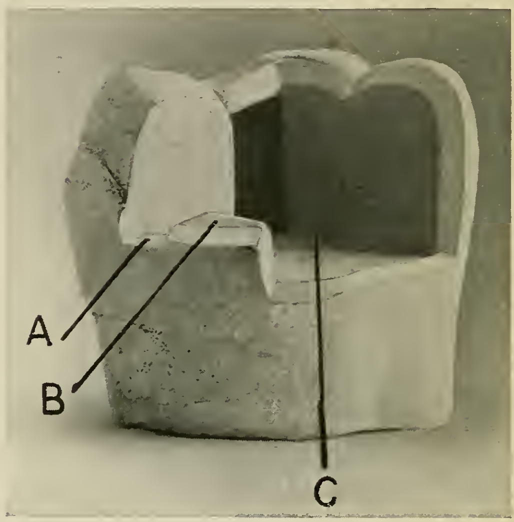


Figure 3 represents a cavity in the disto-occlusal surfaces of a left upper molar. Decay has been very extensive, the pulp has been removed from the tooth, and the disto-lingual cusp, being weakened, has been reduced so that it may be restored with a mass of amalgam sufficient to give ample strength for any occasion. At A is a small slot cut in the lingual wall gingivally to lock the amalgam from any tendency to flow distally from the cavity. At B the wall has a strong bevel which, when covered with amalgam, will overcome any tendency of the wall to fracture. The pulp chamber, filled with cement to the level of the gingival wall, is shown at C. Cavities of this class are encountered very frequently in practice; when they are properly restored with amalgam, the result should be permanent.

ally correct and remains free from the irritation which must result when a banded restoration is used.

It is permissible, in pulpless teeth, to use the pulp chamber as an aid to retention, as this gives added strength and a base

which is better, stronger, and more stable than cement.

4 — Convenience Form

Extension for convenience is less essential for amalgam than for gold. Usually when the preceding forms of retention have been observed, the convenience form is sufficient. It should, however, be observed that suitable condensing instruments will enter the cavity in lines which will produce thorough adaptation.

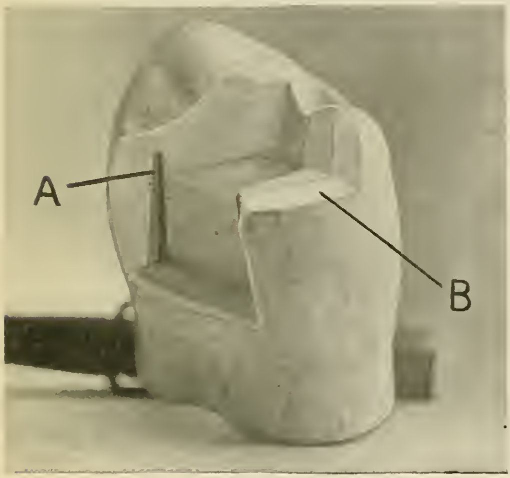


Figure 4 is an upper bicuspid with a cavity in the mesio-occlusal surfaces, involving the lingual cusp. As shown at B, this cusp has been reduced so that it may be restored with amalgam. At A the bucco-axial line angle shows the correct resistance form for amalgam.

5 — Removal of Carious Dentin

All carious dentin should be removed after completing the outline form, to avoid accidents to the pulp.

6 — Finish of Enamel Walls

It is generally believed by the profession that enamel margins should not be beveled for amalgam. A study of the enamel rods, as shown in Figures 6 and 7, will make it clear that a bevel to the cavo-surface angle on the occlusal surface is necessary in instances when the margin approaches a cusp or marginal ridge.

Figure 5 shows an upper molar prepared for an amalgam crown. The gingival walls are extended and squared out as they would be for an operation on either the mesial or distal surface. As both the buccal and lingual walls are weakened by extensive decay, they have been so reduced that the amalgam restoration will have sufficient strength to withstand all the forces of mastication. The floor of the pulp chamber at B is flat and broadened out so that there is only a small amount of dentin left on either the buccal or lingual walls. As all the force of occlusion is applied to this broad flat sub-pulpal wall, very little anchorage is required. There is a very slight undercut around the base of the cavity at C, the bevel from D to E gives added strength. Though such cavities as this seem difficult, they are really simple to prepare and, when a matrix is properly adjusted, they are not difficult to restore.

It is of the greatest importance that all of the surface margins shall be at such an angle that there are no short unsupported rods of enamel at the surface. These are likely to become dislodged, after the filling has

been placed, causing an uneven surface for the lodgment of food solutions and, subsequently, the failure of the operation. To avoid this, the enamel should be cut with the long axis of the rods in the preparation of the cavity, and in finishing the cavo-surface angle a sharp broad chisel should plane the entire depth of the enamel at an angle which will insure the absence of any short rods at the surface.

Dr. Black advocates, in the preparation of the cavo-surface angle for gold foil, a bevel one-fourth of the depth of the enamel. This bevel, which is entirely proper for gold, but would be very unsafe for amalgam, is shown

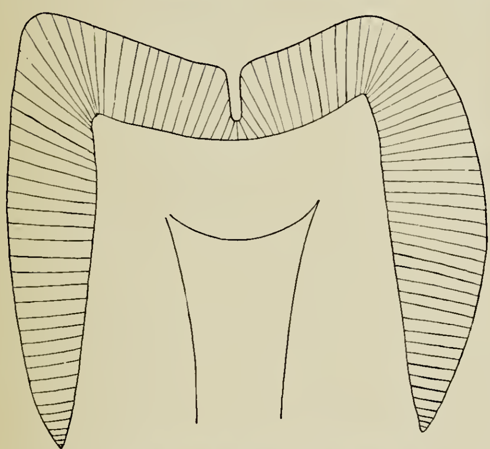


Figure 6 is a diagrammatic representation of the enamel rods, showing the direction in which they are placed in relation to the several surfaces of the tooth. The operator should take advantage of a knowledge of the direction of these rods when cutting and cleaving the enamel for the preparation of cavities for amalgam, especially when forming the cavo-surface angle.

at A in Figure 7. The advantage in strength to be gained by the use of the bevel shown at C in this illustration, for amalgam, will be seen at once.

Figure 8 shows the manner of holding the chisel when planing the enamel wall. The cavo-surface angle is at A, the dento-enamel junction at B.

7 — Making the Cavity Toilet

This represents the final work upon the cavity such as examining thoroughly every margin, surface, and angle with a magnifying glass of low power and wiping or sweeping all of the cavity surfaces with cotton or spunk to remove fine particles of tooth debris which can not be removed in other ways.

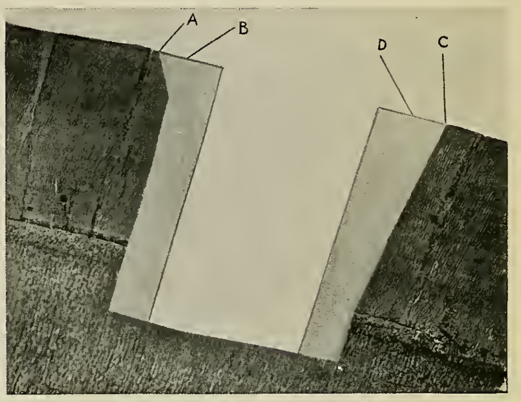


Figure 7 — A section of enamel through which a cavity has been cut into the dentin. At A a short bevel, one-fourth of the depth of the enamel, is shown. This is a bevel advocated by Dr. Black in cavity preparation for gold foil. The correct bevel for amalgam, where the occlusion is a strain to the material, is shown at C. The thin margin of material which is formed when the bevel A is used, is shown at B. A comparison of the bulk of amalgam at D will show the added strength gained by the change in angle. This illustration is adapted from a familiar one in Black's "Operative Dentistry."

Summary of Cavity Preparation for Amalgam

Proper cavity preparation for amalgam is identical with Dr. Black's cavity prepara-

tion for gold foil, with slight modifications, as noted.

Outline Form: As for gold
Modification: Broad outline where occlusal and proximal portions of the cavity join.

Resistance Form: As for gold

Retention Form: As for gold
Modification: Angles slightly more retentive in form.

Convenience Form: Not so necessary as for gold
Modification: Should allow condensing instruments, suitable for amalgam, to enter.

Removal of Carious Dentin: As for gold

Finish of Enamel Walls:
Modification: Bevel entire depth of enamel instead of one-fourth.

Cavity Toilet: As for gold
Modification: Supply missing walls with matrix.

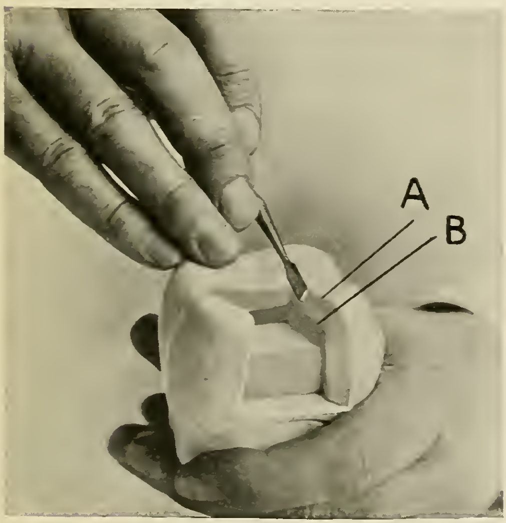


Figure 8 shows a cavity preparation for amalgam in an upper molar, also the position in which the chisel should be held when planing the enamel to obtain the proper bevel for amalgam. The cavosurface angle is at A, the dento-enamel junction at B.

Cement Lining for Amalgam

Many operators advocate a thin lining of cement for the walls of a cavity about to be filled with amalgam, claiming an advantage in that the cement will act as a seal between the amalgam and the tooth structure. With certain classes of amalgam, this is probably an advantage; however it has certain disadvantages. Cement in the thin consistency necessary to its use in this manner is neither strong nor impervious, it is liable to recrystallization and when this occurs moisture will be absorbed at the margins of the cavity and discoloration and future trouble will result.

With the accurately balanced dental amalgam alloys, correctly manipulated, it is our experience that a more permanent result is obtained without the cement intermediary. An amalgam which does not move from the cavity wall will exclude moisture and the bacteria of decay sufficiently to prevent recurrence of caries. In addition to this, amalgam in contact with the tooth substance, either by exerting an antiseptic action, or by some means of which we have no formulated knowledge at the present time, exerts a decided inhibitory action against the bacteria of caries. We do know that some of the metals contained in amalgam have a decided inhibitory action against the growth of bacteria and that their salts are among the most effective antiseptics and disinfectants.

A further disadvantage of the cement lining, when used in thin consistency with amalgam condensed against it, is that it obliterates the definite form of the cavity preparation and especially tends to fill all angles and line angles so that the amalgam does not have the definite form which we anticipated in the preparation of the cavity. When it is desirable to use cement, either

as a base in the pulp chamber, or as a lining for the cavity walls, a cement of the greatest density should be chosen and, after introducing, should be permitted to harden for several hours in order that the bulk changes, which always occur with the oxyphosphates, may fully take place before the amalgam is introduced. After the cement has thoroughly hardened, the cavity preparation should be completed, as previously described, considering the cement as tooth structure and a part of the walls of the tooth.

To Prevent Thermal Shock

When it is desired to prevent thermal shock to the pulp, a thin solution of resin in chloroform may be used with approximately the same advantage as cement. This will not obliterate the cavity lines, neither is it soluble in moisture, and it will neither shrink nor expand. If the cavity is well dried, it will seal the open tubuli.

Matrices for Amalgam

In all classes of cavities where one of the walls of the tooth is missing, it is of first importance that some form of matrix should be used to assist in forming the lost contour of the tooth and to aid in conforming the amalgam to the cavity.

The placing of matrices requires ingenuity and careful workmanship. An effective matrix must be of such form that it can be adapted closely to the gingival margin, but it should not be adjusted so closely that the amalgam can not be adapted completely; it must have such rigidity of wall that it will not be forced out of position, allowing the amalgam to "landslide" from the cavity and fail to be condensed well at the margins; it must be arranged so that contact with the approximating tooth may be obtained, without loss of space; it must be one which can be removed in a short space of time, without distorting the filling.

The matrix which most nearly meets all these requirements is the tied copper matrix, made from 36 gauge sheet copper.

MAKING THE TIED COPPER MATRIX

To make the copper pliable it should be annealed by heating it in the flame and dipping it in water, alternately, two or three times. A strip of the annealed metal, long enough to pass sufficiently about the tooth, should be cut as shown in Figure 9; it does not need to encircle the tooth entirely, but should extend past the margins of the cavity as far as it may without inconvenience. In width it should extend somewhat beyond the length of the tooth occlusally, to give the matrix additional rigidity.

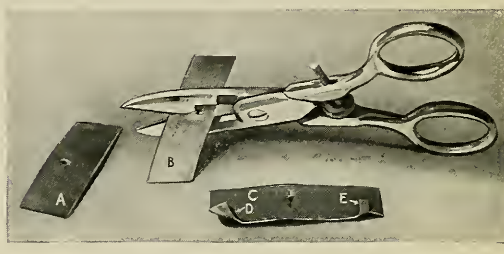


Figure 9 shows the steps in the preparation of the tied copper matrix. A strip of metal cut to suitable size with hole for contact point cut out with the rubber dam punch is shown at A. At B buttonhole scissors are cutting occlusally and gingivally from the contact point to weaken the matrix so that it can be removed easily. C is the completed matrix. Two forms of ears are shown at D and E. Either may be used to hold the ligature in place.

THE CONTACT POINT

With the band in position on the tooth, observe and mark the correct point for the contact with any sharp cutting instrument, as shown in Figure 10. With the rubber dam punch make a small hole where the

contact should come, as shown at A, Figure 9, then with buttonhole scissors, or a sharp instrument, cut the metal occlusally and gingivally from the hole to weaken the matrix so that it may be more easily torn in two when removing it.

Occlusally the slit should be cut to or past the occlusal surface so that an instru-

Figure 10 — Marking the position for contact point with a sharp instrument.

ment may be hooked into it and used to cut the band to the occlusal margin before it is removed. With pliers turn up little ears at the gingival angles, to engage the ligature, and the matrix is ready to be placed upon the tooth and tied. Two forms of ears for the attachment of ligatures are shown at D and E, Figure 9, and the position of the scissors in cutting slits from the contact point is shown at B.

LIGATING THE MATRIX

Place a ligature once around the tooth and matrix and make a single knot, as shown in Figure 11, then pass one end of the ligature around the tooth again, so that the ligature surrounds the tooth twice with only a single tie. Now the ligature should be held taut with one hand while, with an instrument, it is adjusted about the tooth and matrix and carried above the gingival margin, as shown in Figure 12. If the opening for the contact is not in the proper place, it may be adjusted by drawing either end of the ligature. Now tie the ligature with a surgeon's knot and continue to wrap it about the tooth mesially and distally, until the form of the interproximal space is produced as desired, tying finally on the buccal, as shown in Figure 13. After the first tie, avoid making the matrix too tight; leave it so that some of the amalgam will be forced over the margins

Figure 11 shows the matrix, with hole for contact and slits to weaken it for removal, in position upon the tooth; also the first tie of the ligature.

as it will be found almost impossible to carry amalgam perfectly to the margins unless some of it is allowed to pass over them.

If the outline of the cavity is extensive and involves, to any extent, the buccal and lingual walls, the matrix should be

burnished to position and a roll of softened modeling compound should be pressed against it and extended mesially and distally against the other teeth. This, when hard, is easily held in position and will support the matrix against the force of heavy condensing.

As the amalgam is condensed, it will pass through the hole punched in the matrix and will be forced against the proximal surface of the adjacent tooth at the position desired for contact. Heavy pres-

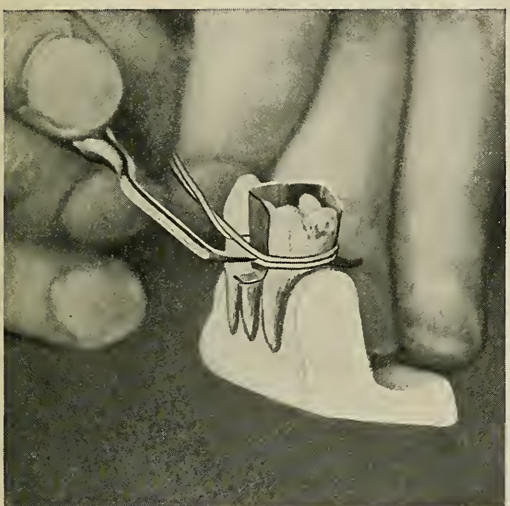


Figure 12 — Holding both ends of the ligature with one hand, while the matrix is adapted about the gingival margin with an instrument.

sure on the amalgam, driving it through this opening in the matrix, will produce a certain amount of separation of the teeth. If more separation is desired, a separator should be placed between the teeth, over the matrix, in such a position that it will not impinge upon the margins of the cavity at any point and so prevent perfect adaptation of the amalgam.

This form of matrix has several advantages; it can be quickly and accurately applied and is very readily adapted to the

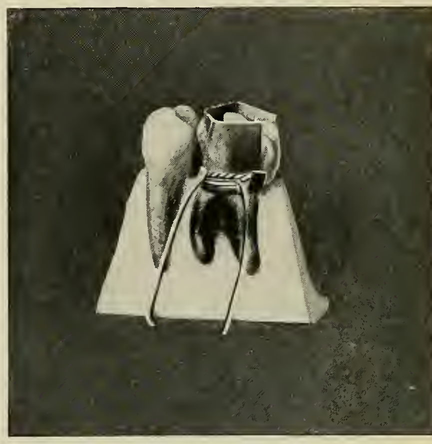


Figure 13 — The completed matrix ligated to position.

peculiarities of the case in hand; in cases where separation is desired a separator can be placed over it and will adhere to the

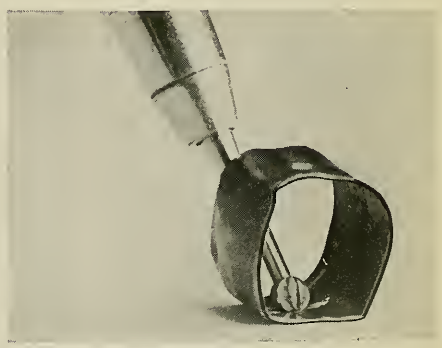
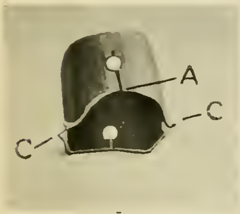


Figure 14 — Drilling a hole for the point of contact with a small round bur, from the inside of the seamless matrix band.

tooth; there is no space lost for thickness of the metal; it is easily removed without disturbing the filling.

THE SEAMLESS BAND COPPER MATRIX

When a complete amalgam restoration, or amalgam crown, is indicated, the seamless band copper matrix may be used to advantage and can usually be adapted quickly and conveniently. A band which will fit the tooth to be restored, as nearly as possible, is chosen and is trimmed and festooned to the gingival outline. The points of contact are marked with any convenient cutting instrument, in the same manner as for the tied matrix shown in Figure 10, and the band is then removed from the tooth and placed upon a block of soft wood while a small round bur, No. 2, is used to drill holes in it at the points of contact, as shown in Figure 14. The entire head of the bur should be allowed to pass through the band at the contact points and the metal immediately around these points should be thinned and made to assume a concave form by grinding with a small round stone. This will produce a better mold for the approximating surface of the tooth and when amalgam is condensed within the matrix, it will assume the form of this mold and, passing through the hole at the contact point, will form a smooth, rounded, normal contacting surface at the desired point.



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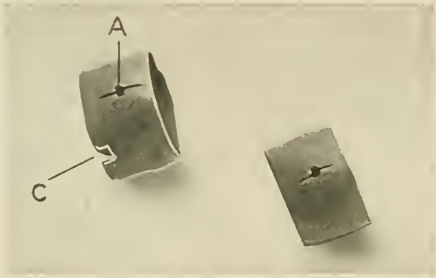

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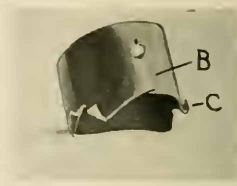

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Figures 15, 16 and 17 show various methods of slitting the matrix bands. Figures 15 and 17 show bands slit from the gingival through and slightly beyond the contact point. At B, Figure 17, the band is lapped to conform more closely to the tooth. Figure 16 shows bands slit both occlusally and gingivally from the contact point, without cutting to either margin. Small ears turned up to engage the ligature are shown at C, in each illustration.

Figure 18 — The first tie of the ligature about the matrix band is shown here. The blunt instrument used for holding the ligature is also used for adapting the matrix about the gingival margin.

CLIPPING THE BANDS

Figure 15 shows the band after the contact hole has been cut and the band has been slit from the gingival edge at A through and slightly beyond the contact opening. This slitting of the band allows it to be lapped, when this is desirable, as shown at B, Figure 17, so that it will conform more

closely to the tooth when it is tied in place, and also allows the band to be removed easily, by tearing, after the amalgam has hardened. Various methods of clipping the bands may be used as conditions and the forms of the teeth vary. It is often advisable to slit the band from the occlusal surface through the contact opening, or it may be slit both occlusally and gingivally from the contact opening, not cutting to either margin, as shown in Figure 16. Small ears, turned up for the purpose of engaging the ligatures which hold the bands in place are shown at C in Figures 15, 16 and 17.

PLACING THE SEAMLESS BAND MATRIX

The seamless band copper matrix may frequently be used without the ligature; when it is desired to use the ligature, however, it should be adjusted about the tooth in the same manner as for the tied copper matrices, previously described. Figure 18 shows the first tie of the ligature, a single tie with a double loop about the band; this illustration also shows the method of adapting the matrix about the gingival margin with a blunt instrument.

It will be noticed that the bands, as shown in Figures 18 and 19, are longer occlusally than the restoration will be when finished. This allows the amalgam to be condensed in excess, producing great density at the occlusal surface.

Both the tied copper matrix, for partial amalgam restorations, and the seamless band matrix, for complete amalgam restorations, are shown in Figure 19.

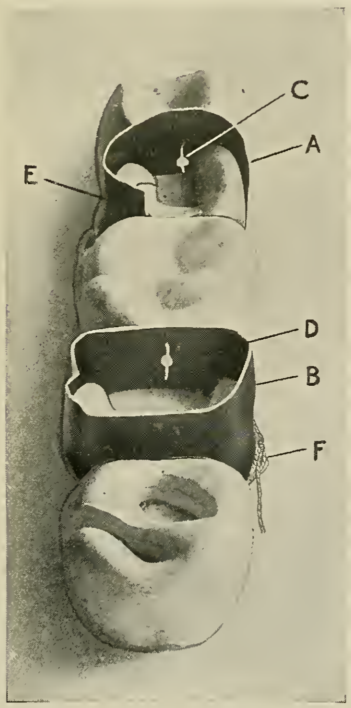

Figure 19 shows two forms of copper matrices in position on the teeth. At A a matrix which does not entirely encircle the tooth is shown in position upon an upper second bicuspid. At C an opening is punched in the matrix at the point where the filling should contact with the distal surface of the first bicuspid. To permit the matrix to be torn away more easily after the amalgam is condensed, the matrix is slit both gingivally and occlusally from the opening C.

A seamless band copper matrix, used in the construction of amalgam crown restorations, is shown at B. The point for contact with the first molar is shown at D, a similar provision is made for contact with the third molar.

After amalgam has been condensed in such matrices, it should be carved until the occlusion is correct and the natural tooth form is restored. If the matrix should interfere with the occlusion it may be ground away until the occlusion is correct. It is usually best to leave such a matrix in position for a few hours at least, as such large restorations must be handled carefully until the amalgam is very hard, otherwise the entire restoration may be broken off at the point of anchorage. The ligatures which hold the matrices in position are at E and F.

Section II. Dental Amalgam Alloys

THE second essential for standardized amalgam technic is the selection of the best alloy that it is possible to obtain for the amalgam. The question, "How are we to know the best alloy to use?", is asked of the writer more frequently than any other. The answer to this question will be found by considering those qualities of an alloy which are essential to permanent results when the alloy is amalgamated and used for the restoration of carious teeth. Practical experience has led to the conclusion that a dental amalgam alloy must satisfy the following requirements:

1. It must amalgamate in such a manner that it will be capable of accurate manipulation by dentists who are familiar with restoration technic.

2. It must possess inherent structural strength and impart this quality to the resulting amalgam. Its amalgam must be sufficiently strong to withstand the continued force of mastication; it must not flow from the cavity under this stress; its margins must endure this force without fracture.

3. It must be chemically and electrochemically resistant to deterioration by tarnishing or corrosion.

4. It must be of the type known as balanced alloy, that is, when properly amalgamated and condensed in the cavity, the amalgam must remain tight to the cavity walls, it must not contract, and must have a minimum and regulated amount of expansion.

5. It must conform to metallographic principles.

6. It must require the minimum amount of mercury.

7. Its color should be pleasing.

8. It must not contain materials which will injure the tissues or discolor them.

It is not an easy matter to incorporate all of these qualities in one alloy, but it is possible and we should not be satisfied with an alloy which fails, in even one particular to meet these requirements.

A careful study of the physical and chemical properties of the various metals which have been used for dental alloys permits us to predicate the probable qualities which the metal will confer upon the alloy and, together with a consideration of methods which have been used for combining the alloy metals, should be helpful in choosing the best alloy.

Dental Amalgam Alloy Metals

Although experiments with other metals have been made none seem to have been found which have added sufficient desirable qualities and the only metals which have been used to any extent for dental amalgam alloys are silver, tin, copper, gold, and zinc. A tabulated comparison of important physical and chemical characteristics of these metals will be found on the succeeding page. Some characteristics which especially affect their use in dental amalgam alloys are noted as follows:

SILVER

Silver occludes twenty-two volumes of oxygen, when molten, which it gives off with great vigor upon solidification. In order to avoid undesirable oxides and resulting eutectics, from this cause, it should be melted in the electric furnace, under hydrogen.

Silver increases in volume when amalgamated, can not be easily manipulated, and is subject to sulphide blackening. In dental amalgam alloys it lessens flow,

Physical Properties of Metals Used in Dental Amalgams

Name	Silver	Tin	Copper	Gold	Zinc	Mercury
Symbol	Ag	Sn	Cu	Au	Zn	Hg
Atomic Weight	107.90	119.0	63.57	197.2	65.37	200.0
Specific Gravity	10.50	7.29	8.95	19.32	7.10	13.60
Atomic Volume	10.20	16.33	7.10	10.20	9.20	14.70
Specific Heat	.0559	.0551	0.0936	0.0316	0.0935	0.0335
*Electrolytic Single Potential Differences	−1.075	−0.083	−0.6067	−1.353	+0.493	−1.027
Electric Conductivity	681,200	93,460	640,600	468,000	186,000	10,630
Heat Conductivity	1.0000	0.1423	0.7198	0.7003	0.2619	0.0148
Linear Coefficient of Expansion	$0.0_4 1846$	$0.0_4 2138$	$0.0_4 1678$	$0.0_4 1470$	$0.0_4 2835$	$0.0_3 1820$
Melting Point °C	961.5°	232°	1084°	1062°	419°	−38.9°
Boiling Point °C	1955°	2270°	2310°	2530°	918°	357.3°
Latent Heat of Fusion Calories Per Gram	24.70	13.83	41.63	16.30	29.86	2.82
Tensile Strength	40,000	6,000	50,000	15,000	5,000	
Malleability	High	High	High	Very High	Fair	
Ductility	High	Medium	High	High	Low	
Color	White	Blue-White	Light Yellow-Red	Yellow	Blue-White	White
Polish	Brilliant	Bright	Brilliant	Brilliant	Fair	Bright
Corrodibility	Very resistant to corrosion	Low when alloyed with silver particularly $Ag_3 Sn$	Low when alloyed with silver and tin	Liable to accelerate corrosion of other metals	Easily Attacked	

*Electrolytic Single Potential Differences between Elements and a Solution containing one Gram Ion of the Element per Liter. The Normal Electrode on the Scale Chosen is −0.56.

Note that the only positive voltage is that of zinc.

hastens hardening, forms the primary freezing network upon which amalgam largely depends for strength, and adds other desirable qualities which may be deduced from its characteristics as indicated in the table of physical properties.

A homogeneous silver amalgam can not be made by triturating silver filings with mercury, since these merely envelope, that is, each grain becomes coated with amalgam, resisting establishment of equilibrium, even when heated moderately. Uniform silver amalgam is produced at the boiling point of mercury, 357° C.

Bomb Amalgam

To determine the structural constituents actually present in silver amalgams, a constitutional study of the series was made by preparing amalgam in the bombs shown in Figure 20. Weighed portions of silver and mercury were placed in the bomb, the

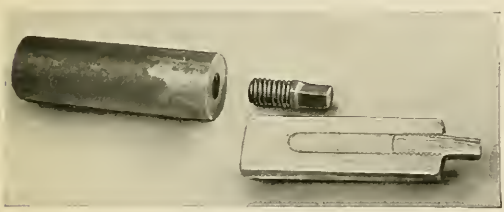

Figure 20 — Steel bombs used to contain alloy and mercury, when amalgamated by heating to the boiling point of mercury.

screw plug was inserted, and the whole was heated in the electric furnace for a suitable period of time, at temperatures ranging near the boiling point of mercury. Naturally the time and temperature necessary for thorough amalgamation increase with the increase in the percentage of silver.

Figure 21 is a photomicrograph of a bomb amalgam containing 43 per cent of mercury; this shows large masses of primary-freezing silver-rich solid solution embedded in the darker, softer mercury-rich solid solution. Up to the percentage of mercury established as correct for dental practice, the silver amalgams are solid solutions of considerable strength and toughness, but the consistency of amalgams containing the percentage of mercury found in the so-called Arbor Dianae (Ag_3Hg_4) reminds one of lumps of moist table salt. This hardens slowly when exposed to the air, supposedly due to the loss of mercury by volatilization, since the vapor tension of the latter is relatively high. Our research indicates that what has hitherto been considered the fundamental reaction of amalgamation: $Ag_3Sn+4Hg=Ag_3Hg_4+Sn$, rests on slight foundation and does not concern dental amalgams.

Neither "affinity" nor "absorption" describes amalgamation. Silver-mercury alloys of any desired percentage of mercury may be prepared readily and, in the dental range, only solid solutions appear. A recent publication states "When silver is amalgamated alone it does not harden to any extent, nor does it disintegrate readily." This statement stands unsupported by data and actual research shows that silver amalgam may be as hard and tough as brass when silver-rich or decidedly different when mercury-rich. "Crepitation" is due neither to silver nor tin amalgam, but to the cold working of primary freezing crystalline grains of the dental amalgam.

TIN

Tin forms a very mobile fluid, when molten, having low chemical affinities thus, in some respects, approaching the precious metals in its chemical behavior. It forms a series of solid solutions, when amalga-

mated, with decrease in volume. In dental amalgam alloys it retards setting, decreases edge strength, increases flow and produces an easily worked mass. It imparts to the alloy its property of solubility, making possible the more ready amalgamation of the copper and silver.

Tin readily dissolves in mercury, the solid solutions rich in tin being reasonably hard and tough, but rapidly losing their desirable industrial qualities with increase in the mercury content.

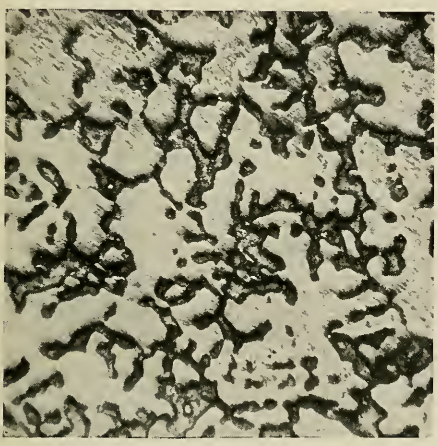

Figure 21 is a photomicrograph of a bomb amalgam of silver and mercury, containing 43 per cent of mercury.

COPPER

Like silver, copper readily forms solid solutions with mercury, near 357° C., amalgamation being correspondingly more difficult at ordinary temperatures and in the copper-rich portion of the series. The amalgam will stand a considerable degree of heat without suffering loss of mercury through volatilization. Copper is an element of strength in dental amalgam alloys, decreases flow in the amalgam, and possesses a desirable coefficient with respect to change of volume upon amalgamation.

GOLD

Gold makes amalgam springy and difficult to pack. It has low tensile strength, is liable to flow, and has a rather high electric potential.

ZINC

Although the use of zinc in dental amalgam alloys has long been condemned by those who speak with authority in the dental profession, its use is still continued and defended by manufacturers of alloys, and it seems well, for this reason, to take up in some detail the physical and chemical characteristics of this metal which may affect the alloy, the amalgam which is made from it, and the general health and welfare of the patient for whom the amalgam is used.

Volatilization and Oxidation

Reference to the table of physical properties shows that the boiling point of zinc is below the melting point of silver and copper. Unless the metals are alloyed at a temperature below the boiling point of zinc, this will cause a volatilization error as an undetermined percentage of zinc will burn out or distil. This error is sufficient to destroy the balance of metals which are placed in the crucible in correct proportions and is further increased by the rapid oxidation of zinc, when molten, even at low temperatures.

Dr. Black: "Zinc is Inadmissible"

As Dr. Black's research has recently been construed to favor the use of zinc in dental amalgam alloys, it seems well to quote here his conclusion on this subject as published in "Operative Dentistry," Volume II, page 312, where he states:

"Experiment in watching fillings for five years shows also that one-half of one per

cent of zinc is inadmissible for the reason that the amalgam will continue to change bulk very slowly for that time and perhaps much longer. Though this change is not large (not more than one to one and one-half points per year, with one per cent of zinc), it will finally destroy the usefulness of the filling. This effect is so subtle that it was not at first discovered."

Dr. McCauley: "100 Points Expansion"

In a paper entitled "Amalgams: Their Manufacture, Manipulation and Physical Properties," read before the National Dental Association, July 25, 1911, and published in "Dental Cosmos," February, 1912, Dr. C. M. McCauley says:

"Zinc is very unfavorable in its action upon other metals in a dental alloy. I made two fillings containing only one per cent of zinc. They behaved very well under the ten days test at first, but measurements made three months later showed nearly 100 points expansion."

Adhesiveness

For the first time in the annals of metallography, the quality of adhesiveness or stickiness has recently been attributed to a metal. It has been stated, erroneously, that zinc adds this quality to dental amalgams. No recognized authorities are quoted in support of this theory.

For one substance to adhere to another, it is necessary for one to moisten or wet the surface of the other, to have gummy or viscous quality. Amalgam might be described as cohesive, while in the plastic state, in the same manner that gold foil is cohesive, but it has no quality of sticking to or adhering to tooth substance. Zinc does not cause amalgam to adhere to the walls of the cavity or its margins; on the contrary, its tendency to produce flow and change of form causes the amalgam to draw away from the margins and walls of the cavity. Moisture proof fillings are obtained by condensing a balanced alloy, properly amalgamated, so tight to the cavity walls that penetration of the oral fluids is prevented.

Toughness

It has also been claimed that zinc toughens amalgam by raising the breaking point. Reference to the table of physical properties shows that zinc has the lowest tensile strength of any of the metals used for dental amalgam alloys.

A Comparison of the Electrolytic Single Potential Differences for a Zinc Alloy Amalgam with Those for a Non-Zinc Alloy Amalgam

Zinc Alloy Amalgam				Non-Zinc Alloy Amalgam			
Positive	VOLTS		Negative	Positive	VOLTS		Negative
Zinc	+.493	Copper	— .607			Copper	— .607
		Tin	— .083			Tin	— .083
		Silver	—1.075			Silver	—1.075
		Mercury	—1.027			Mercury	—1.027

Addition of Single Potentials Gives the Total Voltage Between Any Pair of Positive and Negative Elements

Example: The voltage between zinc and copper is .493V. plus .607V. equals 1.10V. The production of electrical energy in a zinc-copper cell is accompanied by the consumption of zinc.

A series of tests made by Dr. H. A. Merchant to determine the strength of amalgams, under different methods of manipulation and varying conditions, has a direct bearing on this subject. The tabulated results of these tests will be found on page 46. Test No. 1 made with a non-zinc alloy, containing 5 per cent of copper, amalgamated according to directions, showed a crushing strength averaging (for sixteen specimens) 437.5 pounds. Test No. 6, made with a zinc alloy, containing 5 per cent of copper, amalgamated according to directions, showed a crushing strength averaging (for sixteen specimens) 352.5 pounds. After heat treatment of thirty-five minutes at 150° F., approximating the effect of hot drinks and food, the non-zinc alloy amalgam showed a loss of strength of 50 pounds, while the zinc alloy amalgam lost 150 pounds, leaving a net crushing strength of only 202.5 pounds, compared with 387.5 pounds for the non-zinc amalgam.

While the strength of amalgam containing zinc, or other impurities, may be sufficient to resist fracture, it must be remembered that strength is the only safeguard against flow and that resistance of amalgam to flow is increased as the strength increases.

The result of these tests for strength, as well as any other tests outlined in this article, may be verified by any individual dentist or any study club of dentists and all possible assistance in making the tests will be given by the publishers.

Corrosion

A consideration of the effect of zinc on dental amalgam alloys requires some explanation of the phenomena of corrosion of alloys. The process of corrosion may take place in several ways. The simplest of these may be described as chemical corrosion in which the alloy is merely dissolved in the liquid, in the same way that a simple metal is dissolved in an acid, as zinc in an organic acid.

A more complicated process of corrosion occurs from the combined influence of a corrosive liquid and the atmosphere. This occurs very commonly and is frequently observed in the case of copper-zinc alloys. The maximum effect of the corrosion takes place at the surface of the liquid, or when the metal is alternately immersed in the liquid and exposed to the air.

Perhaps the most interesting as well as the commonest type of corrosion is that which may be described as electrochemical. This occurs when two bodies possessing different electrical properties are immersed in contact with one another in a corrosive or conducting fluid. Owing to the difference of potential between the two bodies, an electromotive force is set up, or in other words a galvanic battery is formed and one of the bodies passes into solution.

As zinc is electropositive to the other metals used in dental amalgam alloys, we have, when the alloy is amalgamated and placed in the mouth, all the necessary conditions to produce electrochemical corrosion. The zinc is in contact with the other metals of the amalgam, immersed in a conducting fluid, the saliva, and is dissolved from the amalgam, leaving pits and network oxidation.

The voltage between zinc and any of the negative elements found in dental amalgams may be found by adding their single potentials as found in the table of physical properties or the table on page 22. The voltage between zinc and silver, for instance is .493V plus 1.075V, which equals 1.568V.

Galvanometer Tests

To show the existence of electric currents, local action, and electrochemical corrosion of dental amalgams containing zinc, the following tests were made with the aid of the set up shown in Figures 22 and 23. This is an accurate galvanometer and two copper wires by means of which contact is made with a specimen of amalgam held in the mouth and a gold crown in the same mouth.

Figure 22 — A galvanometer with contact made with a specimen of amalgam made from a zinc alloy and with a gold crown. In a series of tests the deflection ranged from twenty to twenty-five millivolts.

Amalgam cylinders about the size of the crown of a tooth were made up from the most widely known zinc alloys, according to directions given for those alloys. Upon making connections the one per cent zinc alloy amalgams gave a deflection, as shown in Figure 22, ranging from 20 millivolts to beyond the largest scale division of the galvanometer, which is 25 millivolts. In marked contrast the non-zinc alloy amalgam gave a deflection of only 1.75 to 2 millivolts, as shown in Figure 23. In time a smaller deflection results due to polarization or coating of one electrode with hydrogen and in the case of zinc to local action between the metals contained in the one amalgam. This local action practically short circuits the cell (zinc alloy amalgam vs. gold) so that the galvanometer receives only a portion of the original current, resulting in a lesser deflection. The consumption of zinc from the amalgam, due to this galvanic action, is accompanied by pits and network oxidation, as previously described.

Figure 23 — The deflection, when contact is made with a specimen of amalgam made from a non-zinc alloy and a gold crown, is hardly discernible, ranging from 1.75 to 2 millivolts.

Galvanic shock is frequently experienced when a fork or spoon comes in contact with an amalgam filling or the familiar electric tingle may be experienced by inserting the tongue between a sheet of zinc and a piece of silver, such as a silver coin, placed in contact.

Eutectics and Impurities

An alloy whose constituents separate on cooling, or form eutectics which separate on cooling, will almost certainly be corroded on account of the difference in electric potential between the constituents. It is for this reason that alloys forming solid solutions are usually better able to resist corrosion than highly eutectiferous alloys. Figure 24 shows the large proportion of eutectic in an alloy containing 1 per cent of zinc.

Impurities, such as dross, slag, oxides, etc., due to improper treatment of the alloy, are the cause of a similar form of corrosion. The influence of impurities on corrosion has received more attention in the case of metals than in the case of alloys. It is well known that many metals in a pure state are only soluble with difficulty in acids, while the same metals in an impure state are readily soluble in the same acids.

FINDINGS BASED UPON FACTS

In addition to Dr. Black's and Dr. McCauley's charges of change of bulk, it would seem that the charge of responsibility for loss of strength, for pitting, corrosion, and galvanic shock, are amply sustained by the evidence. We conclude, therefore, that a comparison of the physical and chemical qualities of the metals considered, indicates that only silver, tin, and copper should be used for dental amalgam alloys, that gold does not add desirable properties, and that zinc is inadmissible.

Preparation of Dental Amalgam Alloys

Having determined the metals which are suitable for dental amalgam alloys, there remains the determination of a method for combining them in such proportions that their desirable properties shall be retained and their undesirable features eliminated or minimized.

Many methods for the preparation of dental amalgam alloys have been detailed and many theories of abstruse interest have been expounded, but the one principle which has proved to have scientific

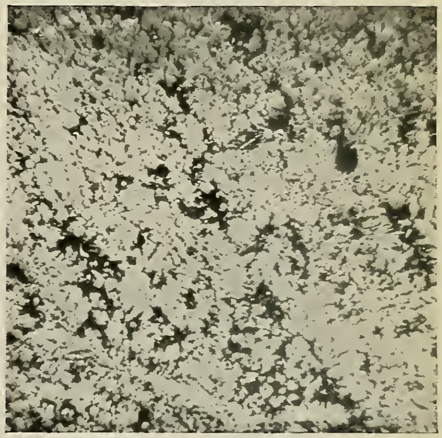

Figure 24 — The eutectic structure of a dental amalgam alloy containing 1 per cent of zinc.

and practical value is that of balancing molecular movements. Dr. Black was the first to devise an amalgam micrometer sufficiently accurate to determine the balancing principle as the correct one for alloying silver and tin in such proportions that shrinkage would be eliminated. Various efforts had previously been made to determine the shrinkage or expansion of amalgam, both by the specific gravity test and by means of direct reading instruments, but these experiments were not carried to a point where authoritative results were secured, and had little practical value in improving the quality of alloys offered to the profession.

The following experiments to determine the proportions in which silver and tin

should be combined to effect a balance between their diametrically opposed qualities are only corroborative of Dr. Black's work.

AMALGAM MICROMETERS

Figure 25 shows the micrometer used by Dr. Black in his research upon amalgam. The smallest divisions are 0.0001 inch and

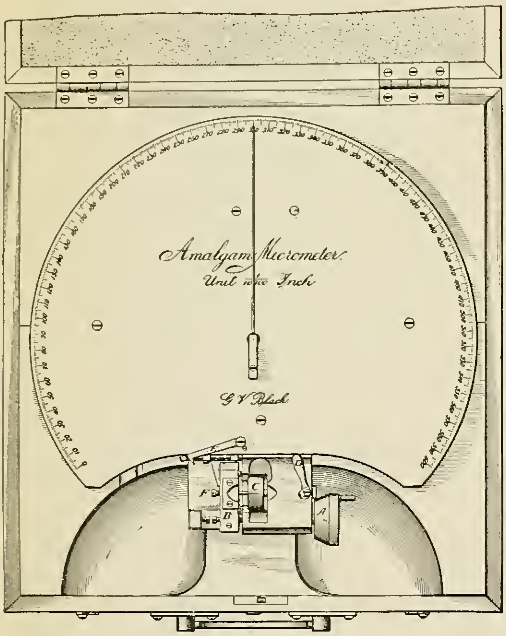

Figure 25—Dr. Black's Amalgam Micrometer. Unit of measurement 0.0001. (From Black's "Operative Dentistry," Vol. II.)

the microscope is used separately to check the readings of the micrometer.

The micrometer used by Dr. Black has been replaced, for these experiments, by a micro-micrometer of original design, which is the most exact and delicate instrument ever used for the measurement of the volume changes of amalgam. As shown in Figure 26, it is a combination of micrometer mechanism with the powerful microscope. Four revolutions of the calibrated wheel measure one millimeter, the wheel bears 250 divisions, thus the least count is 0.001 millimeter, one micron, or 0.00004 inch. With careful work readings may be made as fine as 0.1 micron, or 0.000004 inch, and these readings may be repeated, moving the instrument in either direction. In checking tests made with micrometers of other design, we find that they often give inaccurate results because of friction, lost motion, complex design, and errors in calibration.

The Wedelstaedt tubes, shown at the left of the micro-micrometer and in Figure 27, are those standard in making amalgam tests. They are hardened steel tubes with a definite diameter and depth. The cavity is grooved at the bottom so that the amalgam, when condensed in it, will be held from moving away from the base. While the amalgam is still plastic, a hardened and polished steel point is placed at the center of the filling. The touch point of the micro-micrometer makes contact with this and communicates the amount of expansion or contraction. If the amalgam expands, it can not change the form of these tubes, on account of their strength, but is necessarily forced to protrude from the cavity.

Figure 27 shows empty and filled Wedelstaedt tubes. These tubes fit into the micro-micrometer and are locked in such a way that they may be removed and replaced, at any time, in their exact original position. This is an essential factor in securing accurate results in a

series of tests which is to be carried over a period of several months and leaves the instrument available, in the meantime, for other tests.

To further substantiate the readings of the micro-micrometer, the test filling is placed in a sliding rack, under the objective, and the margins about the tube are examined with the aid of reflected artificial light. In case of shrinkage of the amalgam, the width of the ditch between the amalgam and the tube can be measured.

BALANCING

To determine the composition at which the shrinkage of the tin amalgam offsets the expansion of the silver amalgam, the following tests were made:

An alloy containing 40 per cent silver and 60 per cent tin was amalgamated, according to the usual technic, and condensed in Wedelstaedt tubes. A touch point of polished steel was placed in the center of the filling, the tube was inserted in the micro-micrometer, and measurements were taken and recorded. As the

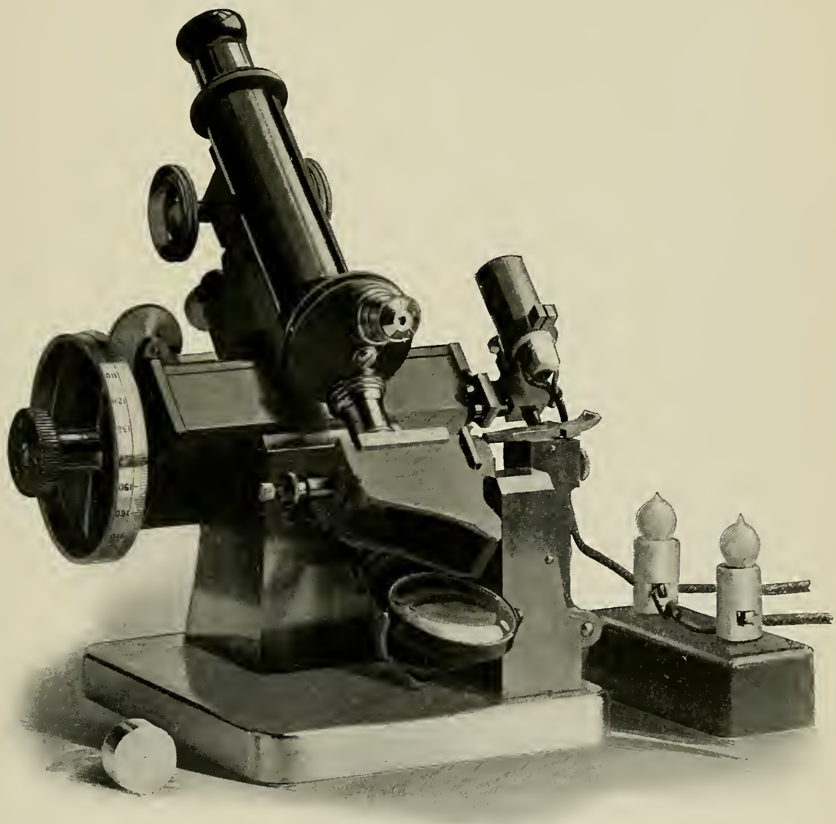

Figure 26
Dr. Crandall's Amalgam Micro-Micrometer, least count 0.00004 inch.

amalgam continued to harden, successive readings were recorded at five minute intervals for a period of one hour, then at successive lengthening intervals. These readings indicated excessive shrinkage. A filling was next made from an alloy of the formula 45 per cent silver, 55 per cent tin: shrinkage was still present, but was a little less than before. These tests were continued by advancing the silver content of the alloy 5 per cent each time, until the ratio 65 per cent silver, 35 per cent tin was reached. At this point, fillings made from fresh cut filings gave two microns expansion, while fillings which were made from annealed filings gave twenty-seven microns shrinkage.

Figure 27 — Wedelstaedt Tubes. A and B, empty; C, tube with test filling; D, test filling, showing great expansion; E, steel tube used to standardize the micro-micrometer to varying temperatures; F, side view of tube, showing guiding slot.

As alloys have the property of aging, or undergoing polymorphic change, further research was conducted upon aged or annealed alloys. At 70 per cent silver, 30 per cent tin, the shrinkage was fifteen microns, at 75 per cent silver, 25 per cent tin, an expansion of twenty-eight microns was noted at the end of two hours, followed by a slight contraction, resulting in a final expansion of 24.5 microns. The silver content was next reduced in stages of 0.1 per cent until, at 74.3 per cent an expansion of three microns was noted after a period of five days.

In a manner entirely analagous to this, the point of balance must be redetermined when copper is introduced into the alloy. When the point of balance is determined, it holds good only for the lot of metals tested. Variations in the purity of metals obtainable, variations in heat treatment which they have received, varying methods by which they have been manipulated, and other factors necessitate the determination of the fineness of every lot of metals procured and micro-micrometer tests of every lot of the finished product.

It is evident that the determination of the balance point for each lot of metals is the only accurate method of arriving at correct proportions to produce a balanced alloy. If the alloy is deficient in silver as much as 0.1 per cent a shrinkage of five microns may occur about the margins of large cavities. This would obviously destroy the utility of the restoration, regardless of the quality of the technic employed.

One micron, as determined by micro-micrometer measurement, corresponds to a ditch or space 0.00004 inch in width, between the filling and the cavity wall. The micro-organisms productive of caries vary in size from 0.4 micron to 0.8 micron. If the width of the ditch, 5 microns, is divided by the diameter of the bacteria, 0.4 or 0.8 micron, it will be seen that a small army of these bacteria could march into the space from six to twelve abreast. Recurrence of caries must attend this invasion of bacteria. We leave for your consideration the possibilities which may occur with those alloys which show a con-

traction of from ten to seventy-five microns. Without the aid of precision instruments which will detect the minutest movements of an amalgam while it is hardening, it is impossible for the manufacturer to give assurance of a desirably balanced alloy.

The Proximate Analysis of Alloys

The physical properties of alloys which give them their industrial importance depend largely upon their proximate composition, or constitution, as revealed by thermal analysis and microscopical examination. The chemist reports the analysis of brass, for instance, as 70 per cent copper, 30 per cent zinc, while the report of the metallographist is concerned with such data as the character and distribution of the solid solutions, defects in the metal, heat treatment, mechanical defects, results of strength of materials tests, grain structure, extent of deformation, and beneficial modifications in composition or production.

In the great majority of cases, two or more metals can be mixed with one another, in the molten condition, in any relative proportion, and in a manner analagous to the formation of well known organic or inorganic solutions. However, compounds may form, and metals varying widely in such physical properties as melting point may form mutual solutions to such a slight extent as to be practically immiscible.

According to the number of metals contained in the series, alloys are classified into binary, ternary, and higher systems; while, according to their behavior in the molten state and upon solidification, they are classified as chemical compounds, solid solutions, and eutectics.

CHEMICAL COMPOUNDS

The chemical compounds of one metal with another do not, in general, follow the law of valence, but are of the type known as molecular. The resulting chemical compound differs much less in its properties from those of its component metals than is the case with strong chemical compounds. It is in accordance with this general idea that it is concluded that even those metals which do form definite chemical compounds are relatively feebly combined. The metallic compounds usually have a limited range of stability and at certain points in the equilibrium diagram are resolved into other bodies. Great difficulty is experienced in isolating most of these compounds and the chemical constitution of comparatively few of them has been determined with certainty.

The evidence for considering that a structural constituent is a definite combination of two metals, instead of a solid

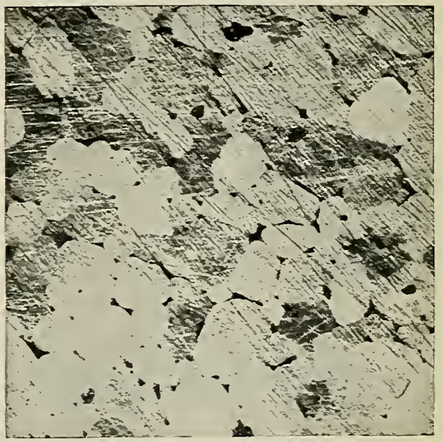

Figure 28 — Photomicrograph of Ag_3Sn, a well established metallic chemical compound.

solution, is not always as conclusive as would be desirable. On the liquidus the formation of a compound is often indicated by a sudden change of curvature and the whole range of composition throughout which the compound separates from the

liquid mixture corresponds to a distinctly separate branch of the liquidus. At other times the change of curvature is almost or quite indistinguishable, but in this case the compound usually forms solid solutions with the component metals, or with other compounds of the series, and can not be isolated. When the occurrence of a compound is shown by a distinct branch of the liquidus, this frequently exhibits a point of maximum temperature, which is the freezing point of the pure compound. The composition of the mixture which shows this maximum freezing point is difficult to determine with exactness, since the curve is somewhat flat, but it is found to agree closely with a simple atomic proportion of the two metals. Under the microscope this compound is distinguished as a new structural constituent which differs in properties, such as color, hardness, and rate of etching, from the component metals, eutectic, or solid solution. At a certain composition the whole of the section appears to consist of this new constituent and, if analyzed, the alloy is found to contain the metals in proportions corresponding very nearly with those represented by the peak of the liquidus curve. It is reasonable to suppose that a chemical combination of the metals in a series of alloys exists only when —

Figure 29 — Cold-rolled brass, a well known example of metals in solid solution.

1. At a certain composition, it constitutes the whole of a just solid metal;

2. On chemical analysis is found to contain the metals in approximately simple atomic proportions;

3. Gives rise to a separate branch of the liquidus curve, showing a temperature maximum at a composition very close to that given by analysis;

4. Has physical properties such as color, hardness, density, electrical conductivity, etc., which differ sharply from other structural constituents of the series.

A well established metallic chemical compound which fulfills all these conditions is Ag_3Sn. A photomicrograph of this compound is shown in Figure 28.

While a number of binary metallic compounds have been established, according to Dr. Rosenhain no ternary metallic compounds have been determined to date.

SOLID SOLUTIONS

The distinguishing characteristic of a solution is that the particles of the dissolved substance can not be detected and can not be separated by mechanical means. For example, in a mass of copper containing tin, the tin can not be detected under a microscope of the highest powers, nor can it be separated by mechanical means. The alloy solidifies and crystallizes as though it were a pure metal and the mixture of the two metals is so intimate that there is a strong analogy between it and a liquid solution.

Examples of metallic solid solutions of wide industrial use are shown in the photomicrographs of cold rolled brass, Figure 29, and copper-tin alloy, Figure 30. The

latter is an alloy of the bronze series which was cooled too rapidly for the beta to gamma transformation to take place. The black areas represent primary crystal skeletons of beta, chilled at 725° C. The particular solid solutions, i.e., alpha, beta, gamma or delta, found in this series of alloys, have a very important effect upon physical properties.

Mechanism of the Formation of Solid Solutions of Two Metals

Let us assume that a certain proportion of the metal tin, of relatively low melting point, is alloyed with, or dissolved in, the metal copper which has a higher melting point. The copper may be considered as the solute and the tin, as the solvent. It is believed that, when solidification begins, homogeneous crystals of tin and copper are formed, but that they contain a smaller proportion of the fusible metal, tin, than the liquid bath, which is thereby enriched in tin. On further cooling these crystals grow, but the crystalline matter now deposited contains more of the metal tin than the crystals first formed, although still less than the molten bath which is further enriched in tin, and so on, the crystals growing through successive additions of crystalline matter, containing increasing proportions of the dissolved and readily fusible tin, and approaching, therefore, although not reaching the composition of the molten metal, until finally the last drop solidifies. A homogenizing anneal will bring the whole mass to the same composition.

Figures 31, 32, 33 and 34 show a balanced silver-tin-copper alloy in process of homogenization. Figure 31 shows the dendritic structure of the alloy upon solidification, while Figure 34 shows the completely homogenized alloy. Figures 32 and 33 are intermediate stages during homogenization.

EUTECTICS

The eutectic is a conglomerate of metals, has a constant composition, always freezes at the same temperature, and is the lowest freezing alloy which can be obtained in the series. The eutectic structure is composed of the different constituents in juxtaposition. The constituents of a eutectic may occur in curved plates or laminae, or in globules, and either or both may be simple metals, solid solutions, or compounds. Types of eutectic structure are shown in Figures 35 and 36; they are very characteristic and are not easily mistaken.

The manner of employing cooling curves in the construction of the equilibrium diagram for a eutectiferous series, is shown in Figure 37. The eutectic E has the longest eutectic halt, corresponding to the greatest evolution of heat on cooling. The other alloys of the series evolve an amount of heat at the eutectic temperature propor-

Figure 30 — Another example of metals in solid solution. Copper-tin alloy, 73 per cent copper, magnified 45 diameters, etched with acidified ferric chloride.

tional to the amount of eutectic which they contain.

In the ternary dental amalgam alloy, silver-copper-tin, properly balanced, the copper content should be within the solid solution range, and the tin content small

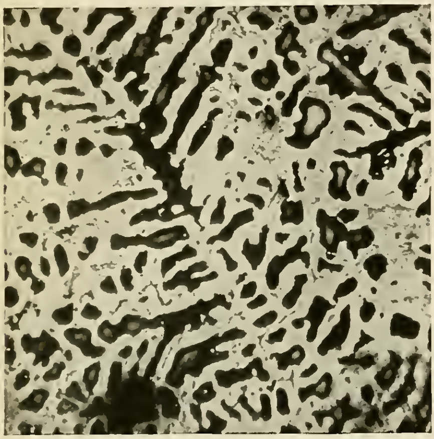

Figure 31 — A balanced silver-tin-copper alloy remelted and slowly cooled, showing solid solution.

enough to prevent extensive formation of eutectic. The silver content should be sufficiently high to form the strongest primary freezing amalgam network. Thermal analysis and photomicrographs are used to indicate the proportion of eutectic and solid solutions, the latter being the desirable constituent of dental amalgam alloys. Silver can not be reduced beyond a certain point without producing an alloy which is highly eutectiferous and weak upon amalgamation.

Aging and Annealing of Dental Amalgam Alloys

Annealing, and heat treatment in general, effects profound changes in the physical properties of alloys. The freshly cut dental amalgam alloys require a high percentage of mercury for their amalgamation, and are so extremely rapid setting that very few operators are able to employ them satisfactorily. Annealed alloys require less mercury and are modified in their setting qualities so that they may be correctly manipulated.

DR. BLACK'S EXPERIMENTS

After a series of experiments which are outlined on page 308, Volume II, "Operative Dentistry," Dr. Black reached the following conclusion in regard to the changes produced in alloys by annealing:

"Conclusion: The cut alloy is made abnormally hard by the violence in cutting, the same as metals are made hard by hammering. By the processes above detailed, it becomes annealed to normal. The

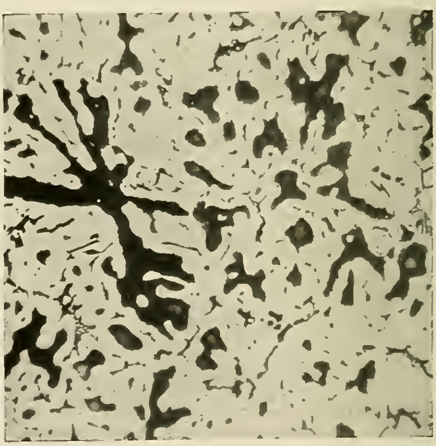

Figure 32 — A balanced silver-tin-copper alloy partly homogenized.

change was produced by heat. This effects a change in the affinity for mercury and the rapidity of combination with the results named above. Why, is unknown, but the *fact* stands all tests. It is a primary physical phenomenon."

FURTHER RESEARCH UPON AGING PHENOMENA

Incidental to our research upon dental alloys and amalgams, the following observations have been made. It would seem that they offer a reasonable explanation of the slower rate of amalgamation which characterizes aged filings of dental amalgam alloys.

Freshly cut alloy is rapid setting for a number of reasons, chemical, physical, and physico-chemical. The particles from the cast ingot are in a state of metastable equilibrium, due to suspended transformation of part of the alloy into the normal proportions of compound, solid solution, and eutectic.

Filing, or cold work, endows the freshly cut particles with strain potential which, according to the electrolytic theory of solution, favors more rapid amalgamation. In order to better understand the effect of cold work and annealing, it should be pointed out that the structure of metals is crystalline.

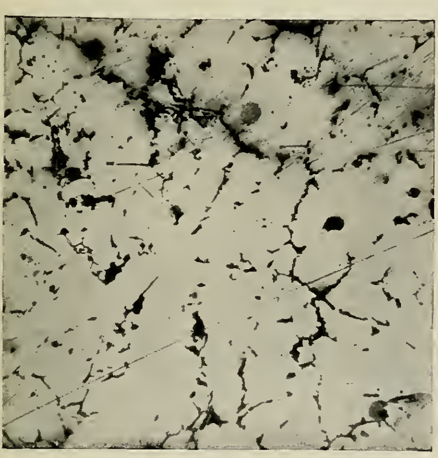

Figure 33 — Another stage in the homogenization of a balanced silver-tin-copper alloy.

It appears that the particles of freshly cut alloy are full of cracks, thus presenting more surface to the attack of mercury or, more accurately, the severely strained metal has developed a finer crystalline structure and, of course, the fine crystals will dissolve more rapidly in mercury than the same amount of material in the form of large crystals, or crystals of a more resistant system.

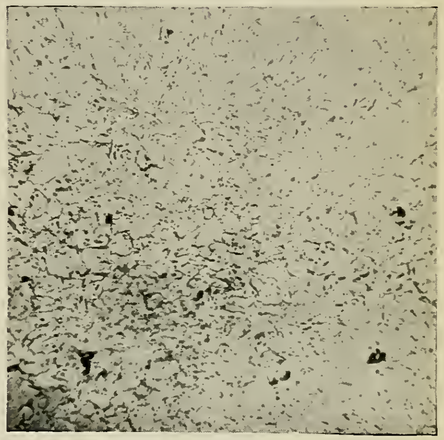

Figure 34 — A balanced silver-tin-copper alloy fully homogenized.

Changes in temperature and pressure frequently give rise to different crystal structures and change in physical state, or molecular arrangement, is accompanied by alterations in physical properties. When metals or alloys are severely strained by compression, tension, or bending, the original crystals are broken up and replaced by much finer units. Microscopical examination of a metal strained beyond the elastic limit reveals fine lines on the crystal grains termed slip bands. These slip bands are cleavage planes, for the most part intimately connected with the formation of new small crystals.

UNAGING AN AGED ALLOY

Alloy which had been aged by annealing was unaged, during these experiments, after repeated grinding in a mortar followed by heavy pressure exerted by a

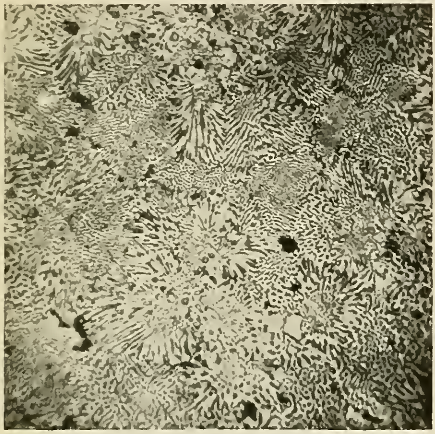

Figure 35 — Photomicrograph of silver-copper eutectic.

modified Brinnel machine. The freshly cut alloy amalgamated with equal parts of mercury was quick setting and only a minimum of mercury could be expressed in a vise after amalgamating. The annealed alloy was slower setting and much more mercury was expressed with the same amount of pressure applied with a vise. After the annealed alloy had been subjected to the grinding and heavy pressure mentioned, it reassumed the properties of a freshly cut alloy, in regard to time of setting and the amount of mercury which it was possible to express in a vise after amalgamation.

AMORPHOUS MATERIAL

Another important factor affecting a freshly cut alloy is the formation of so-called "amorphous material," upon filing or severely straining by heavy pressure. The appearance of "amorphous layers" marks an increase in the following physical properties: hardness, tensile strength, volume, heat of solution, and solution pressure.

Amorphous material etches and amalgamates more rapidly than crystalline or annealed metal. Howe states that, "The plastically deformed metal etches faster because, being lighter, that is bulkier and less closely packed, it offers greater surface for attack; because its amorphous metal lacks crystalline bond which in itself opposes solution and every other kind of attack; and because in being a mechanical mixture of amorphous and crystalline metal, it has local differences of potential, which are such frequent accelerators of corrosion."

Our dissolving agent is mercury and, digressing, we have found it to be a valu-

Figure 36 — Copper-Antimony eutectic. This illustration and Figure 35 show characteristic eutectic structure.

able etching reagent, which enables us to watch the growth of amalgam crystals under the microscope, and to bring out upon a polished surface constituents of an alloy not readily amalgamated.

ANNEALING

If thorough amalgamation took place, equilibrium conditions in the alloy filings would be of less importance, but as a matter of fact partial amalgamation takes place and the alloy particles are enveloped with amalgam, and not completely dissolved.

In order that the balance point of an alloy may remain constant for at least a year, it has been found advisable to anneal, or age, the filings in a manner determined by careful experiment. This heat treatment reduces the setting rate of a high grade alloy so that it comes within the range of careful manipulation, makes possible the use of a lower percentage of mercury and reduces the amount of expansion of the alloy upon amalgamation.

The effective annealing period and temperature is a function of the chemical elements of which the alloy is composed and also of the proportions of its structural constituents. The proper annealing temperature and period must be determined for each alloy in order to obtain the particular condition desired.

OVERANNEALING

Overannealing enlarges the crystalline grains of the alloy, reducing its strength, and affecting its working qualities upon amalgamation. This change may take place through the use of too high temperature for a short period of time, or from exposure to ordinary room temperature over a longer period of time.

In regard to this change Dr. Black says, in "Operative Dentistry," Volume II, page 311:

"Tubes of alloy were put up for time tests, some of which yet remain after twelve years, and frequent tests have been made. Shrinkage and expansion remain unaffected. The amount of mercury required diminishes, the amalgamation becomes easier, the setting becomes slower, and the strength of the amalgam is gradually reduced. An alloy that makes a crisp amalgam which sets quickly, such as should always be used in practice will, if kept two or three years at ordinary room temperatures, come to make rather a sloppy, slow-setting mass. If the alloy is exposed to the heat of the sun or otherwise to unusually high temperatures, these changes will be rapid in proportion."

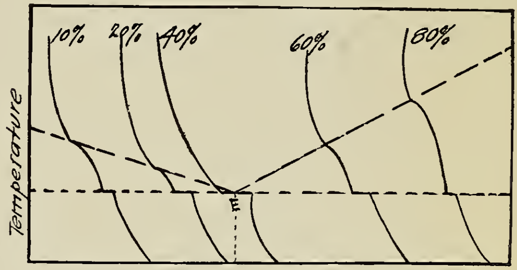

Figure 37 shows the manner in which cooling curves are employed in the construction of an equilibrium diagram for a eutectiferous series.

CRUSHING STRENGTH OF OVERAGED ALLOY

To determine the loss of strength of amalgam made from overaged alloy a series of dynamometer tests has been made with alloy two years old. Alloy and mercury were used in equal parts, heavy mallet force was used for condensing, and some excess mercury was expressed during condensing. The average strength shown over a period of two and one-half months was 348 pounds, while tests made under the same conditions with alloy less than one year old showed a crushing strength averaging about 500 pounds.

We conclude that dental amalgam alloys should not be annealed beyond the zero point, except for cases where extremely slow setting alloys may be desirable, and where the strength of the amalgam is not an essential factor. As even low temperatures bring about this change if continued over a long period, it is not advisable to use alloys which have been manufactured for a considerable length of time, or alloys of which the date of manufacture is unknown.

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Dental Cosmos.

Section III. Amalgamation

HAVING considered correct cavity preparation and the requisite qualities of dental amalgam alloys, we come to the third essential of standardized amalgam technic, correct amalgamation, of equal importance with these and the succeeding steps of the operation. Amalgamation may be described as a process of melting and selective freezing.

SELECTIVE FREEZING

In order to make the process of selective freezing somewhat clearer, there may be constructed a hypothetical binary solid solution diagram, as shown in Figure 38, considering the tin amalgam as one element and the silver amalgam as the other. Let the tin amalgam contain 30 per cent mercury; likewise, the silver amalgam. Suppose the tin amalgam freezes at 100° C. and the silver amalgam at 400° C. Let A-B be the amalgam under consideration; at K, 300° C., a drop or so of silver-rich solid solution, having the composition shown at O, freezes out; the remainder being liquid. This selective freezing continues until the last drop freezes at L, 175° C., having the composition shown at N or M. Thus the resulting alloy froze in the area KOLM; it will show core structure and consist of the summation of alloys ranging in composition from O to M. The primary freezing silver-rich network, or core structure, possesses a composition in the neighborhood of O; the crystalline grains are relatively fine; the whole is a fairly strong structure. This represents the amalgam when first placed in the mouth. Now suppose the amalgam to be at blood heat and every meal up to the temperature of hot drinks. The amalgam becomes homogenized; the whole returns to the composition B; the grains become larger, weaker, and coarsely crystalline; the process is accompained by volume change. This change is the more readily accomplished the larger the proportion of low melting metal or eutectic.

AMALGAM MANIPULATION

Dental amalgams are partial solutions of a metal or alloy in mercury; the state and condition of the solution have a decided effect upon the final result of an operation

for which the amalgam is used, the method of manipulation affects the result to an equal degree.

There is a wide variation in the ability of dentists to manipulate amalgam and an unwillingness on the part of some to spend

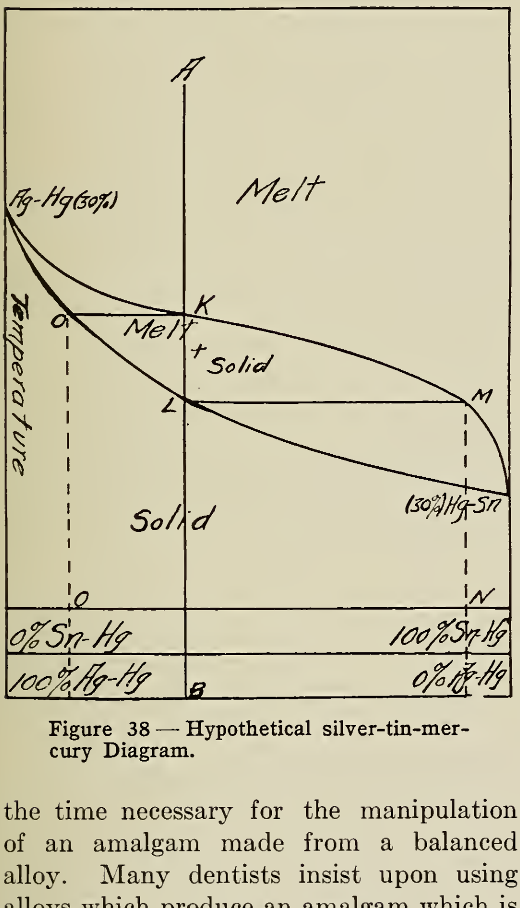


Figure 38 — Hypothetical silver-tin-mercury Diagram.

the time necessary for the manipulation of an amalgam made from a balanced alloy. Many dentists insist upon using alloys which produce an amalgam which is plastic and easily manipulated, although it is well known that such amalgams do not produce permanent results. Neither should an alloy be used if its amalgam sets so quickly that it is beyond the ability of the skillful operator to manipulate it. Such alloys require high percentages of mercury to make their amalgam sufficiently plastic to permit good manipulation, and it may be stated, as a principle of amalgamation, that the strength of amalgam varies inversely with the mercury content. The best alloys, of necessity, make a rather quick-setting amalgam, but it is possible to regulate their setting qualities so that any operator should be able to manipulate them successfully.

MERCURY

Mercury seems to affect the physical properties of most metals injuriously; for instance, if mercury is alloyed with nickel, under the influence of heat and pressure, the metal develops a coarse granular structure and will not bend, as formerly, without breaking. Fortunately silver and copper require larger percentages of mercury than those used in ordinary practice, before their valuable properties are decreased beyond the permissible limit.

The purity of the mercury used is a factor in the success of an amalgam operation, as the mercury of commerce frequently contains, in addition to the oxides and sulphides noted as scum upon the surface, copper, lead, zinc, or tin, which when added to the alloy may so change its proportions that the permanent usefulness of any operation for which it is used will be destroyed.

At ordinary temperatures mercury coats a particle of alloy and forms a protecting or uniting envelope of amalgam, while very little mercury diffuses to the center and none will be found at the center of a fairly large specimen. In this process, termed partial amalgamation, there is a gradient in the mercury percentage from the mercury-rich exterior to the center containing, perhaps, none. Figure 39 shows this gradation in the composition of an alloy particle partially dissolved in mercury.

PROPORTIONS OF MERCURY AND ALLOY

The correct ratio of alloy to mercury is an essential factor in the final result, as an excess of mercury will cause a shrinking alloy to shrink more, an expanding alloy to expand excessively, and a very closely balanced alloy to shrink first and then expand. Obviously this is because there

Figure 39 — Diagram showing mercury gradient in a partially dissolved alloy granule.

is sufficient mercury present to produce the maximum action possible from the metals, while if the mercury is limited, it can only produce action on the amount of alloy dissolved and must then cease. To avoid this sloppy excess of mercury, which not only produces excessive movement, but weakens the amalgam, both alloy and mercury should be weighed with a reasonably accurate balance. Weighing will prove a decided economy as one soon acquires the ability to judge the approximate amount required for cavities of various sizes, while it is impossible to guess the amount when pouring the materials from a container. We should plan to have plenty of amalgam for each filling, without repeating the mix, but it is useless extravagance, especially in the case of large fillings, to amalgamate two or three times the required amount.

Sufficient mercury should be used to produce an amalgam of such consistency that fluid mercury will appear on the surface of the mass, while it is being rapidly rolled in the palm. The manufacturer should determine the ratio of mercury which will produce this consistency for each lot of alloy, as the dentist can only estimate unless he uses the micro-micrometer and dynamometer, and spends considerable time. It is necessary to determine the ratio for each lot of alloy, as it is impracticable to make all batches of alloy so that the proportion of mercury required will be the same. For this reason, we should pay no attention to the directions for the ratio of mercury if the same directions are used with every batch of alloy.

There should always be a slight excess of mercury, to make the best amalgam, but this excess should be expelled as manipulation progresses.

THE MORTAR AND PESTLE

Many methods of amalgamating alloy and mercury have been advocated, and all, perhaps, have some advantages for certain varieties of alloy. The accurately balanced dental amalgam alloys have proved most successful when triturated in the wedgwood mortar. One of these will be found in nearly every dental office, but the pestle which accompanies it is usually worse than useless because of its shape and size. The pestle should be so shaped that it will fit into the contour of the mortar and large enough to cover most of the floor, so that as much as possible of the alloy will be worked continuously. The handle of the pestle should be generous in size to permit

a firm grasp. A pestle which is correct in form is shown in Figure 40.

The roughness and porosity of the new wedgwood will prove to be a source of considerable annoyance at first, as the amalgam will adhere to the mortar and is difficult to remove. The deeper pores will become filled with the amalgam, in time, and the trouble will then cease. It will hasten matters to grind the inner surface

Figure 40 — Wedgwood mortar, with large pestle fitting into the contour of the mortar, correct in form for triturating alloy and mercury.

of the mortar with powdered emery, or other suitable abrasives, until it is smooth.

PRECEDING AMALGAMATION

Before the amalgamation of the alloy with the mercury is begun, everything about the cavity should be in readiness for condensation and the completion of the operation. The instruments for condensing should be at hand and should be tested in the cavity, to make sure that they have the proper form to reach the angles of the cavity. There should be no delay after the alloy and mercury are amalgamated before condensing is begun.

AMALGAMATION

To amalgamate the alloy, begin with a circular motion of the pestle, using very light pressure so that the mercury will not be forced away from the alloy. As soon as the alloy has taken up the free mercury, slightly heavier pressure should be used on the pestle, and this should be continued until all of the granules of the alloy have been coated and free mercury is not apparent in the mortar. When this point is reached, the amalgam should be removed to the palm where it should be rolled and worked rapidly. This rapid rolling seems to bring out the excess mercury better than other methods and also insures a better solution by rapidly changing the position of all of the alloy granules.

As the amount of mercury used is insufficient to form a chemical combination with the metals of the alloy, the particles of alloy are only partially dissolved and a uniting envelope of amalgam is formed, leaving an undissolved integral granule which assists in retaining the original strength of the alloy.

A series of dynamometer tests made to determine the comparative effect of partial and thorough amalgamation upon the strength of amalgam resulted as follows:

ALLOY No. 178

Alloy eight parts — Mercury ten parts.

Ground with mortar and pestle ¾ minute. In palm 3¼ minutes. Total 4 minutes.

Granules well dissolved in mercury. All excess mercury removed.

Heavy mallet force for condensation.

Average crushing strength test over a period of 2½ months, 375 pounds.

ALLOY No. 178

Alloy and Mercury equal parts.

Ground with mortar and pestle ½ minute. In palm ½ minute. Total 1 minute.

Granules well coated but not dissolved in mercury. All excess mercury removed.

Heavy mallet force for condensation.

Average crushing strength test over period of 2 months, 464 pounds.

THE AMALGAM DYNAMOMETER

The dynamometer used for this and other tests of the compressive strength of amalgam, described in this article, is shown at Figure 41. Cubes of amalgam .085 inch are made in the block shown in the lower part of the illustration; these are placed in the steel jaws of the instrument and a compressive force is applied, by means of the screw head at the right. As the pressure is increased, the dial registers the pressure in pounds; when the amalgam is crushed, one hand of the dial remains stationary, registering the exact amount of force which has been required to crush the amalgam. A good amalgam resists a pressure of from 350 to 600 pounds; many amalgams are fractured before the pressure reaches 200 pounds.

It must be borne in mind that these tests are made with very small fillings, .085 inch, with fillings of ordinary size the strength would be increased proportionately. It is evident that this large factor of safety is necessary when one considers that amalgam is but slightly ductile and that the full force of occlusion is often exerted upon frail margins, which are tested to their utmost to resist fracture. Not only this, but as the strength of amalgam is increased, the tendency to flow is diminished. It is as important that amalgam should resist flow as that it should resist fracture. The leaking margins that we so frequently observe are more often from flow than from shrinkage. Flow of amalgam is its tendency to move under pressure, either sustained or intermittent; it is only a change of form and not, in any way, an increase in the bulk of the filling, hence, if the filling moves in the cavity in the least degree, a leak must be created at some point.

Tests of amalgam for flow are also made with the dynamometer. Cubes of amalgam of the same size as those used for measuring strength, .085 inch, are placed in the jaws of the dynamometer and pressure is applied until the dial registers one hundred pounds. The small micrometer dial, at the right of the large dial, is set at zero.

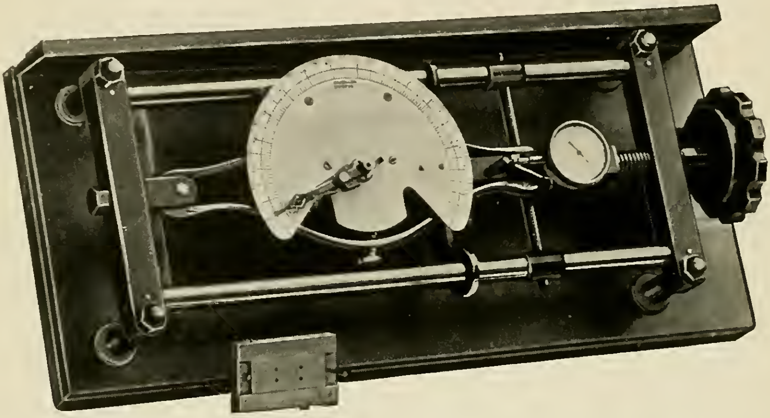


Figure 41 — Amalgam Dynamometer used for measuring the compressive strength of amalgam.

As the amalgam is compressed the micrometer dial registers the amount of compression.

EXPRESSING EXCESS MERCURY

The excess mercury, necessary for amalgamation, should be removed from the amalgam by expressing it through muslin with flat nosed pliers. In experiments with annealed alloys we have found that a lesser amount of pressure applied through an interval of time will remove more mercury than a greater amount of pressure applied and immediately removed.

It is difficult to state the exact consistency at which amalgam should be placed in the cavity. The most desirable consistency is that obtained by expressing all of the mercury in excess of the amount required for perfect adaptation, as the greatest strength in the amalgam is secured by bringing the undissolved particles of alloy as closely together as possible. Unless the operator realizes clearly how very difficult it is to adapt amalgam thoroughly, he should experiment on cavities in extracted teeth, under conditions as nearly normal as possible, splitting the teeth and examining the adaptation with a magnifying glass after the filling has thoroughly set. Possibly a magnifying glass will not be necessary. Because of this difficulty of adaptation and because amalgam with *all* the excess mercury removed sets very rapidly, it is very rarely advisable to begin condensing with amalgam as dry as it is possible to make it.

MIXING SOLUTIONS

Amalgam should be kept free from water, saliva, and chemical solutions, during its manipulation, as any moisture which comes in contact with it tends to decrease its strength about one-third. There are on the market a variety of solutions for "washing alloys, to make them white and aid amalgamation." These solutions may possibly remove tarnish from some alloys, but this does not make the filling any whiter. Their principal harm lies in moistening the granules and preventing amalgamation. The effect of a two per cent HCl solution when used for this purpose is shown by the following result of tests made with the dynamometer:

ALLOY No. 10

Alloy five parts — Mercury six parts.
2% HCl mixing solution used.
Amalgam packed with heavy hand pressure.
Average crushing strength, 283 pounds.

ALLOY No. 10

Alloy five parts — Mercury six parts.
No mixing solution used.
Amalgam packed with heavy hand pressure.
Average crushing strength, 389 pounds.

Other tests show that alcohol, water, or saliva, coming in contact with the alloy before amalgamating, have a similar effect.

Section IV. Instrumentation and Condensation

HAVING made all preparation possible for the completion of the operation before amalgamating the alloy and mercury, we should begin to place the amalgam in the cavity and condense it immediately after the excess mercury is expressed from the amalgam.

To secure the greatest strength in the amalgam, we must express a still further amount of excess mercury while condensing

and bring the undissolved portions of the alloy granules as closely together as possible. This is best accomplished by the use of properly shaped condensing instruments with the hand mallet. The hand mallet not only supplies the stress necessary

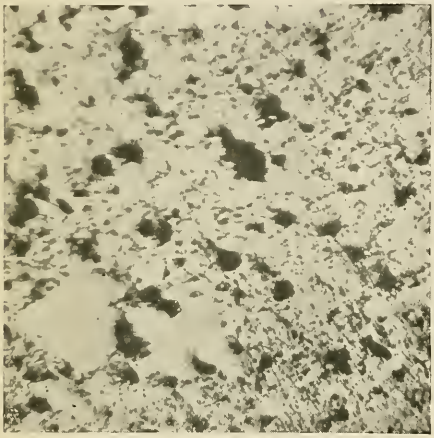


Figure 42 — Photomicrograph of dental amalgam, showing accidental voids resulting from insufficient condensation.

to condense the mass but, in addition, agitates and vibrates the alloy granules, reducing the void volume and bringing to the surface further excess of mercury which may then be removed. Dr. Black found that the average amalgam filling contained about fourteen per cent of air space. It is unnecessary to say that these air spaces or voids are not desirable.

ACCIDENTAL AND INHERENT VOIDS

Voids are of two kinds, accidental and inherent. Accidental voids, which are much the larger, result from insufficient condensation. They may and should be minimized by proper condensing, with heavy pressure. Inherent voids are due to the diffusion of excess mercury from the mercury-rich portion of the alloy into the alloy-rich portion. The black areas seen in Figure 42 are accidental voids in a mercury-rich amalgam, poorly condensed. Figure 43 shows the same amalgam thoroughly condensed and containing a smaller proportion of mercury. The alloy-rich portion of the amalgam appears as large white grains, the small dark areas are almost entirely inherent voids. Amalgam of this structure possesses the highest crushing strength and the minimum volume change. It is the structure which should be attained in amalgam restorations, as determined by physical tests, metallographic investigation, and actual clinical observation.

THE RELATION OF VOIDS TO VOLUME CHANGES

We find that the phenomena accompanying voids throw some light on the volume changes of amalgam. An observed fact

Figure 43 — Photomicrograph of dental amalgam with smaller inherent voids, resulting from the diffusion of mercury into the alloy granules.

is that with excess mercury a tin-rich alloy shrinks more and a silver-rich alloy expands more than normally is the case. As previously noted tin forms a shrinking solid

solution with mercury, and silver an expanding one. When an excess of mercury is used, it finally becomes effective in forming more tin-rich amalgam, accompanied by increased shrinkage; contrarily, more silver-rich amalgam is accompanied by increased expansion.

A secondary phenomenon causing expansion in the silver-rich amalgam arises from the fact that the particles grow in diameter as the envelope of amalgam increases in thickness and the interstitial adhering mercury diffuses toward the center, leaving inherent voids. On the other hand, tin simply melts in mercury without formation of particles of larger diameter and voids. The explanation of this behavior involves a discussion of molecular physics and physical chemistry which will be considered in a later publication.

BEGINNING CONDENSING

In placing the amalgam, it is often advisable to begin with a small piece that is not as dry as the remainder of the mix. It can be condensed and adapted more perfectly than the very dry amalgam and the excess mercury can be removed from it, as it makes its appearance, during the condensing. Instruments which will carry the amalgam into the angles and over the margins of the cavity, as shown in Figure 44, should be used to begin condensing. Force should be applied first in the angles of the cavity, then the condenser should be stepped so as to reach the margins last.

HEAVIER PRESSURE

After the base of the cavity is covered, larger pieces of amalgam and larger condensing instruments may be used, as the size of the cavity will permit, and the force may be greatly increased as the size of the condensers and the density of the amalgam increase. This stage of the operation is shown in Figure 45.

ADVANTAGES OF HEAVY CONDENSING

Amalgam is treacherous in that it readily gives the appearance, on the surface, of thorough condensation, and only careful examination will reveal the defects caused by a failure to thoroughly seat and condense it. One of the advantages of condensing it to the density described is that this may compress the dentin walls, that is it may spring them apart so that their elasticity will produce a continued force upon the amalgam, an effect similar to the advantage gained by the use of gold foil. This continued force exerted by the compressed walls will, to an extent, overcome the disadvantage of any minute volume changes occurring in the bulk of the restoration and will produce a contact of the filling with the cavity walls which is proof against leakage.

Figure 44 — Beginning condensation with a small instrument, condensing into the angles and margins of the cavity.

CONDENSING OVER ALL MARGINS SIMULTANEOUSLY

The excess of mercury which will come to the surface as a result of the heavy force used in condensing should be removed with suitable instruments and drier amalgam should be added. Finally, to fill the cavity, a large excess of amalgam should be added and a condensing instrument, sufficiently large to cover all of the margins simultaneously, should be used, with the hand mallet, to drive the amalgam tight on all margins. This simultaneous pressure over all of the margins is necessary as on account of the semi-plastic nature of amalgam it would be impossible to make a wide area of margins tight by passing from one point to another. Naturally pressure *down* at one point will produce pressure *up* at another point and a leak will result. The large excess of amalgam used has the advantage of absorbing any excess of mercury from the cavity margins and gives strength at this point, where strength is most essential; it also protects the margins from the blows of the condenser and makes possible closer adaptation to the cavity walls and margins.

Figure 45 — The use of a condenser as large as the cavity will permit.

Figure 46 shows the use of a large condensing instrument which produces pressure over all the margins simultaneously.

EFFECT OF HEAVY CONDENSING

To determine the comparative strength of amalgam from which the excess mercury has been removed and which has been thoroughly condensed by the method outlined here, the following tests were made: Fifty fillings, .085 inch cube, were made in steel dies, all from the same alloy. Twenty-five had the excess mercury removed by placing the amalgam in a small piece of muslin and expressing it with flat-nosed pliers and were thoroughly condensed by mallet force. Twenty-five were made by expressing the mercury between the thumb and fingers and were condensed as thoroughly as possible by hand pressure. At varying intervals the same number of fillings from each lot were crushed in the dynamometer and a record was made of the crushing strength. The average strength of those which had been thoroughly condensed by mallet force, after removing the excess mercury through muslin with pliers, was 514 pounds; of those with the usual amount of mercury remaining and condensed by hand pressure, 385 pounds, that is, 129 pounds or 33½ per cent in favor of mallet condensing and a minimum of mercury.

CORROBORATIVE TESTS

A series of tests made recently by Dr. H. A. Merchant confirms the result of previous tests of methods of manipulation and condensation and also shows the effect

of heat upon amalgams manipulated and condensed in various ways.

The object of the heat treatment is to produce an amalgam of the same structure that occurs in fillings subjected to changes of temperature from hot food and drinks. It may be objected that 150° F. is the maximum temperature experienced in the mouth; however, the same effect occurs at lower temperature but requires a longer period of time. The maximum temperature was chosen merely to obviate unnecessary delay. Dr. Merchant's findings are tabulated on page 46. Some of the more important are noted following:

TESTS OF A BALANCED NON-ZINC ALLOY

Test No. 1 was made with a non-zinc alloy of 80 mesh filings. The alloy and mercury received only light initial trituration. With mallet force for condensing, the small granules were driven together so that the excess mercury was largely driven off. As little of this mercury was absorbed by the alloy, the resulting amalgam was silver-rich. The loss of strength resulting from heat treatment was small.

Test No. 2. The only variation from test No. 1 was the use of pressure for grinding the alloy with mercury so that the granules were partly crushed. This cold work partially unaged the alloy, so that it retained more mercury than in test No. 1. The effect of this higher percentage of mercury is graphically shown in the resulting loss of one-half the strength of the amalgam under heat treatment.

Test No. 3. In this test the same alloy was used as in test No. 1 and No. 2. The object of this test was to learn the effect of large percentages of mercury such as have been advocated, recently, by a number of prominent dentists for the purpose of making air-tight fillings in steel tubes. Amalgam of this strength would flow and leave a crevice about the margins of a tooth which would soon defeat the object of the operation. The fallacy of a mercury-rich amalgam is evident when its weakness is considered.

Tests Nos. 4 and 5 show the volume change of a non-zinc alloy, due to heat treatment. It will be noted that heat produced practically no change in the volume of amalgam when the parts of mercury were only slightly in excess of the parts of alloy. However, in test No. 5

Figure 46 — Condensing a large excess of amalgam over all the margins of the cavity, by the use of a large condenser which will cover all the margins simultaneously.

where the percentage of mercury is too high, the sloppy amalgam resulting suffers great volume change. This effect should be borne in mind by those inclined to use amalgam in a sloppy condition.

Amalgam Tests Made by Dr. H. A. Merchant, Randolph, Nebr.

No. of Test	1	2	3	4	5	6	7	8	9
Composition	A Balanced Non-Zinc Alloy With 5% Copper					A Balanced Zinc Alloy With 5% Copper			
Dimensions of Cube	.085 inch			Wedelstaedt Tubes		.085 inch		Wedelstaedt Tubes	
Parts Alloy	10	10	10	65 grs.	60 grs.	9	10	63 grs.	63 grs.
Parts Mercury	10	10	14	71 grs.	85 grs.	11	10	81 grs.	81 grs.
Method of Amalgamation: In Mortar	Light Initial Trituration Rolled Till Bright Surface Appears	Heavy Initial Trituration Rolled Till Bright Surface Appears	2 Minutes	Light Initial Trituration Rolled Till Bright Surface Appears	2 Minutes	2 Minutes by Directions	Light Trituration Rolled Till Bright Surface Appears	2 Minutes	2 Minutes
Method of Amalgamation: In Palm			1.5 Minutes		1.5 Minutes	2 Minutes by Directions		1.5 Minutes	1.5 Minutes
Mercury Expressed	2 grs.	0.5 grs.	3 grs.	6 grs.	16 grs.	2 grs.	½ gr.	10 grs.	14 grs.
Methods of Condensation	Mallet Force	Mallet Force	Hand Pressure	Mallet Force	Hand Pressure	Med. Hand Pressure	Mallet Force	Mercury Packed Out	Hand Pressure
Date Made	5-9-'16	5-9-'16	5-9-'16	5-7-'16	5-8-'16	5-9-'16	5-17-'16		5-13-'16
Date Crushed	5-13-'16	5-13-'16	5-13-'16			5-13-'16	5-21-'16		
No. Specimens	16	16	16			16	16		
Average Crushing Strength	437.5 lbs.	417.5 lbs.	291.25 lbs.			352.5 lbs.	280 lbs.		
Heat Treatment	35 Minutes at 150° F.					35 Minutes at 150° F.			
Average Crushing Strength	387.5 lbs.	210 lbs.	150 lbs.			202.5 lbs.	250 lbs.		
Strength Lost	50 lbs.	207.5 lbs.	141.25 lbs.			150 lbs.	30 lbs.		
Final Contraction: Before Heating								13.1	15.9
Final Contraction: After Heating								7.5	24.6
Final Expansion: Before Heating				9.2	37				
Final Expansion: After Heating				8.2	53				

TESTS OF A BALANCED ZINC ALLOY

Tests Nos. 6 to 9 were made with a balanced zinc alloy, containing 5 per cent of copper. Test No. 6 shows the decided loss of strength resulting from the zinc content and the large proportion of mercury required for this alloy. Tests Nos. 8 and 9 show the effect of heat treatment upon this shrinking amalgam, the excess of mercury used causing excessive movement in the direction of the balance of the alloy.

Section V. Contour and Finish of the Restoration

AFTER the amalgam has been condensed it should not be disturbed until it has crystallized sufficiently so that it can be carved. If the condensing has been thoroughly done, as described, crystallization will usually take place in a very few minutes. The carving should be begun as soon as the density of the mass will permit, always before the amalgam has set.

CARVING THE OCCLUSAL FORM

It is of the greatest importance to the function of mastication that the occlusal form of the tooth should be accurately restored. Flat or curved surfaces do not permit the holding or tearing of foods; the occlusal surfaces must have their proper form of cusps, sulci, pits, and occlusal planes, otherwise the masticating surface, as a unit, will soon form the habit of shifting the burden of mastication to those surfaces which more properly function. A comparison of the smooth, polished surfaces, shown at C in Figure 47, with the carved surfaces of A and B will show at once the superiority of the latter in grasping and tearing food.

The restoration of the occlusal surface to nature's form, so that it will work in harmony with the antagonizing teeth, is an especial advantage in the case of extensive restorations or amalgam crowns. Before beginning to carve these restorations the matrix should be ground with a stone in the engine handpiece until it does not interfere with the occlusion or with the carving. The excess of amalgam should be carved, or ground down, and the occlusion tested, before the amalgam has thoroughly hardened.

As rotary instruments cut only concave surfaces and the cusp surfaces are mostly convex, we find little use for engine driven instruments, for this purpose, except for removing large excesses of amalgam and approaching the general form of the tooth. The carving which differentiates the restoration from the filling can be done correctly only with hand-carving instruments.

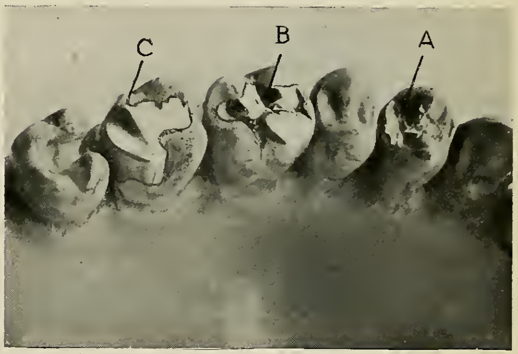


Figure 47—At A and B are amalgam restorations carved to the correct occlusal form. Their superiority over the smoothly finished surface at C, for holding and tearing food, is readily apparent.

As the carving proceeds it should be tested frequently until it is correct. A high degree of art may be attained in this work by studying the natural tooth forms and practicing their reproduction. As it is impossible to smooth these carved surfaces with disks and the mandrel, they should be smoothed, as soon as they are carved, with pumice carried on pointed tooth polishing brushes.

Figure 48 — Removing the matrix by tearing.

REMOVING THE MATRIX

When the tied copper matrix has been used, it may be removed at this point, if the restoration is not extensive. The ligature should first be cut and removed, then with a sharp pointed instrument finish cutting the slit in the matrix from the contact to the occlusal edge, to further weaken it. With pliers, or the fingers, grasp one end of the matrix, while holding the other end firmly against the tooth, tear it with a twisting motion from the contact to the gingival, as shown in Figure 48, and remove it. The other section may be removed readily.

The seamless band matrix, used for extensive or complete restorations, is removed by cutting through the buccal surface with a sharp instrument or stone, as in Figure 49, and tearing the band out in sections. This should rarely be done before the amalgam has thoroughly set, never in less than twenty-four hours.

The necessary carving having been done, the excess of amalgam removed, and the filling given the correct form, the patient should be dismissed with an appointment for the final finishing of the restoration.

Many dentists complain that patients will not return for this final finishing, this is usually because they do not understand that it is essential. They should be told that the operation is not complete and that they must return.

THE FINAL POLISHING

The finishing and polishing of an amalgam restoration is accomplished in the same manner as the finishing and polishing of a gold foil restoration. The proximal surface from the point of contact to the

Figure 49 — Seamless band matrix with slits ready for removal.

gingival margin should be finished with knives, files, and strips. Disks and stones are useful upon the other surfaces, but a disk should never be allowed to pass over the contact point and flatten it. The point of contact should not be a surface contact, but should be gently rounded, so that food will pass through the embrasure and be freed readily, yet not so reduced that food will pass over it. If the occlusal surface has been carefully smoothed with brush wheel and pumice, directly after carving, there will be no trouble in obtaining a good final finish with the brush wheel and chalk, after the amalgam has set. For the final finish of the other surfaces buff wheels and brush wheels, carrying chalk and other fine abrasives should be used.

Section VI. Profitable Fees for Amalgam Restorations

THE amalgam operation which we have outlined is not a cheap operation and should not be considered by the patient as a cheaper substitute for a gold crown or other work which usually brings a better remuneration.

The question of adequate compensation for amalgam work is, perhaps, one of the most vital ones confronting the dentist today. When it is considered that from fifty to seventy-five per cent of all dental operations are amalgam operations, its importance is at once apparent. As with most situations in need of betterment, the remedy probably lies not in some sweeping and miraculous change to be brought about at once, but in a gradual improvement brought about through various influences.

The dentist should have a more thorough realization of the importance of restoring even an ordinary pit or fissure cavity to correct anatomical form. He needs to realize that the cost of the amalgam alloy he uses is almost a negligible factor in the cost, to him, of the completed operation. He should know and constantly impress upon his patients that the value of his services to them lies not in the use of porcelain rather than gold, or of gold rather than plastic materials, but in the restoration of a diseased member to its proper form and function in the mouth, and in the permanence of the operation.

EDUCATING THE PATIENT

There are many patients with ill fitting gold crowns, with extensive amalgam fillings, overhanging at the gingival margin, with contact points improperly shaped, or lacking, who believe that the consequent loss of tissue and the constant discomfort of food retained between such teeth, is a necessary result of a dental operation. There are others who think that an amalgam filling must shrink and will need to be replaced in a year or two at most; that it will necessarily blacken and discolor the tooth.

The dentist is the patient's only authoritative source of information on dental subjects; a careful and simply worded explanation of his dental needs, and of the care and time necessary to produce a result which will conserve his health, rather than help to undermine it, should gain his complete co-operation and should convince him that the operation is sufficiently important to command an adequate fee.

DEMONSTRATION

When necessary, illustrations, a typodont with fillings, or carved plaster models may be shown to demonstrate the correct

restoration, in comparison with the gold crown or the amalgam filling which lacks contour and occlusal form.

ADVANTAGES OF THE AMALGAM RESTORATION

Patients are willing to pay an adequate fee for good dentistry. When they are made to understand that they are getting

Figure 50 — Recurrence of decay due to movement of the amalgam, from the use of unbalanced alloys, to improper cavity preparation, lack of matrix, insufficient condensation, and lack of adaptation. None of these fillings show proper contour, occlusal form, or contact.

value commensurate with the amount paid, there will be very little objection to reasonable fees. The advantages of the operation should be carefully elucidated, especially in cases where large amalgam restorations are needed.

Explain that the contour of the enamel at the gingival margin does not need to be destroyed, as it must be if the tooth is crowned; that the adaptation of the margins is so perfect that micro-organisms can not enter the tooth and cause recurrence of decay; that there are no rough margins to irritate the soft tissues and set up inflammation, which is often followed by most serious results; that the whole restoration is solid metal, it can not wear out, it will not absorb foul liquids as a mass of cement, such as a crown contains, will always do; that the restoration requires as much time and skill as a crown does; that the material is the best of its kind and that the operation will permanently restore the occlusal form and masticating function of the tooth.

Nothing which has been said here, however, should be taken to countenance an advance in fees which is not justified by the service rendered. There is no value inherent in a higher priced alloy which justifies the increase of fees if the quality of the result is not, at the same time, advanced commensurately. An alloy made to render the highest service may be misused by improper amalgamation, by undue excesses of mercury, by insufficient condensing, and may be placed in a cavity so poorly prepared that the result is of very little final value to the patient.

Amalgam work like that shown in Figure 50, with recurrence of decay due to improper cavity preparation; want of the matrix; improper condensing; lack of contact, proper contour, and occlusal form; and showing movement due to the use of unbalanced alloys, is overpaid at any price.

When a careful technic is followed throughout the operation, however, and an alloy made and tested by scientific methods is used, the resulting amalgam restoration should give better service than the average inlay, or a gold foil restoration such as can be made by the operator of average ability, and the service rendered should be the final consideration in determining the amount of the fee.

Making a Standardized Dental Amalgam Alloy

by

Albert Sellner, Chief Chemist of

The Cleveland Dental Mfg. Co.

METALLOGRAPHY is placed at the head of testing and investigating methods by the largest manufacturers of metal products because the physical properties of metals and alloys, to which they owe their definite industrial importance, are much more intimately concerned with proximate composition, revealed by the metallographic microscope, than with ultimate chemical composition.

The application of metallography to dental products possesses novelty and offers a considerable advantage. While it is necessary to know the percentage composition of a dental amalgam alloy, the determination of some of its physical properties is much more important. For instance: Is it a solid solution or eutectic? Is it homogenized or heterogeneous? Was it annealed properly and understandingly, after cutting, or merely heated up blindly? What structural constituents are formed upon its amalgamation? Does its amalgam shrink or expand, corrode or waste away, and how much? Such is the nature of the numerous questions which must be answered.

Figure 51 — Mr. Sellner weighing the metals for Crandall's Scientifically Tested Non-Zinc Alloy.

The living organism demands that modern science study, with extreme care,

the metals and alloys which may affect its health and general welfare. The anatomy of a metal is its physical and chemical composition; its biology, the influence exerted upon its constitution by various treatments, thermal and mechanical; its pathology, the action of impurities and defective treatments upon its normal constitution. Metallographic dissection reveals the physical association of proximate constituents and features relating to desirable or objectionable attributes.

Figure 52 — Dendritic or "tree" structure in a sample of copper containing 0.3 per cent phosphorus. Magnification 150X. Reichert metallographic apparatus.

It is pleasing to know that the dental profession is becoming very aggressive in metallographic research as witnessed by the papers appearing under the auspices of the National Dental Research Association.

The preliminary work necessary to the production of a standardized alloy has been done by men whose devotion to the dental profession has led them to spend time and effort in making the investigations which have been the foundation for our work. Our task has been to adapt their methods to the production of alloy in larger quantities, without deviating from the scientific methods and accuracy which were responsible for the results which they obtained.

An outline of the method of manufacturing a balanced alloy follows:

Selection of Materials

As gold has not proved to add desirable qualities to dental amalgam alloys and zinc has proved to be decidedly deleterious, the only metals used for Crandall's Scientifically Tested Non-Zinc Alloy are silver, tin, and copper. Our problem of the selection of materials resolves itself, therefore, into the effort to obtain these three metals in the purest possible state. The utmost precaution is taken to purchase only the purest metals obtainable and these undergo

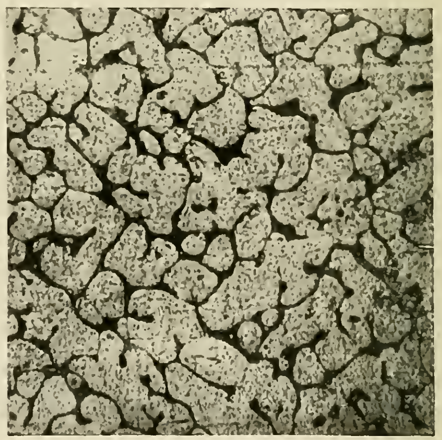


Figure 53 — Cast copper with 0.1 per cent oxygen. Even this very slight impurity unfavorably affects the physical properties of the copper to such an extent that it should not be used for dental alloys.

further purification and rigid physical and chemical tests in our laboratories. Photomicrographs of the structure of these metals reveal the character and distribution of impurities and afford an absolute check on claims made for purity.

It is a comparatively easy matter to obtain silver and tin of the necessary purity for a balanced alloy. Silver is furnished to us in the form of ingots from the United States Assay Office. Our tests for fineness must show 999.8. The allowable impurity for tin and copper is 0.01 per cent.

Copper of this high standard of purity is obtained with considerably more difficulty than is the case with silver and tin. Regularity of crystalline structure has been pointed out as the ultimate test of the purity of metals. The fallacy of this contention is shown by the following statements summarized from Sauveur's Metallography:

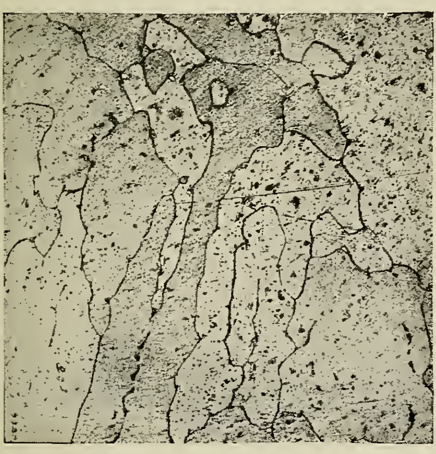


Figure 54 — Cast copper with 0.2 per cent oxygen.

Microstructure: When a properly prepared sample of a pure metal is examined under the microscope, the revealed structure generally presents the appearance of a polygonal network, an indication that the metal is composed of irregular, polyhedral grains, each mesh or polygon of the network representing a section through a polyhedron.

Idiomorphic Crystals: When the fluidity of a substance and other conditions are such that the formation and growth of the crystals are given free play, perfect, and sometimes very large, crystals are produced. These perfect crystals, with faultless geometrical outlines, perfect cubes, for instance, are called idiomorphic crystals.

Figure 55 — Cast copper with a small percentage of impurity, causing core structure.

Allotrimorphic Crystals: When the free development of the crystals is hindered by less favorable crystallizing conditions such, for instance, as collision or contact with other crystals likewise in the process of formation, the regular external form is not preserved and the resulting imperfect crystals are called allotrimorphic crystals, also, but more seldom, anhedrons or faceless

crystals. Such crystals are said to have taken their shape from their surroundings. It should be noted, however, that allotrimorphic crystals, like idiomorphic crystals are composed of crystalline matter. An allotrimorphic crystal may be regarded as resulting from the mutilation of an idiomorphic crystal, the mutilation affecting the external shape only and not the crystalline character of the substance. *That is, a pure metal usually exhibits irregular grain structure.*

The tree-like or dendritic structure sometimes observed in photomicrographs of copper has also been erroneously taken for an evidence of purity of the metal. It may be caused by 0.3 per cent of phosphorus as in Figure 52.

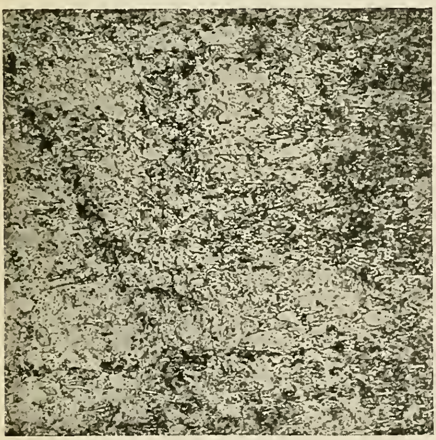


Figure 56 — Electrolytic copper.

Ordinary copper may contain impurities of lead, antimony, tin, iron, arsenic, cuprous oxide and, in some instances, zinc, bismuth, sulphur, selenium, tellurium, or other elements peculiar to copper from a certain district, or to certain methods of refining. In general, metal dealers are limiting impurities to cuprous oxide, arsenic, antimony, and bismuth. Phosphorus used for reducing cuprous oxide ($2P+5Cu_2O=P_2O_5+10Cu$) slags off or sublimes, for the most part. It has been argued that cuprous

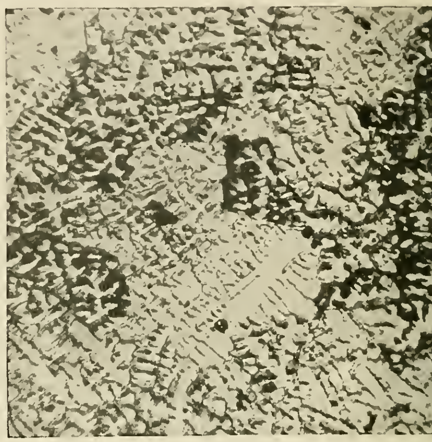


Figure 57 — Another specimen of impure copper containing dendrites or "trees."

oxide, within the commercial limits of 0.4 per cent to 1.2 per cent may oxidize impurities and permit formation of copper arsenate, bismuthate, and so on, but we have found that this brittle constituent is undesirable for obvious reasons in a product which must be balanced.

Again 0.1 per cent oxygen, meaning 0.9 per cent cuprous oxide, forms 25.7 per cent of eutectic. Figure 53 shows such a copper which is unfit for use as its continuity and desirable physical properties are too greatly affected. Small percentages of oxygen are hardly accurately determined by ordinary analytical methods, but micrometric analysis of the eutectic appearing in a photomicrograph presents most accurate

results. This is accomplished by measurement of the eutectic areas with a planimeter, or by the count of squares method.

Copper is unique in its capacity for absorbing oxygen and furnace gases, hence the use of the electric furnace for melting

Figure 58 — Conductivity copper, used in the manufacture of Crandall's Scientifically Tested Non-Zinc Alloy. Note its beautiful, clear structure, as compared with coppers containing slight impurities. Magnification 80X.

it is imperative, as all effort to obtain pure metals avails very little if they are afterward contaminated by melting in a gas furnace.

Figure 54 shows copper with 0.2 per cent of oxygen; Figure 55 copper with a slight amount of impurity showing core structure; Figure 56 electrolytic copper; Figure 57 another impure copper with tree structure or dendrites.

The copper purchased and used for Crandall's Scientifically Tested Non-Zinc Alloy is of that highest quality known as conductivity copper; its beautiful clear structure is shown in Figure 58 and Figure 59.

Melting

To those unfamiliar with the manufacture of dental amalgam alloys, it might now appear that, having assembled the pure metals, it would be a simple matter to melt them together, and that the resulting ingot would be pure, containing silver, tin, and copper, in the same proportions which were originally placed in the crucible. Various obstacles, however, prevent this. If the metals were simply melted together, under ordinary conditions, the mass would absorb oxygen with a resulting partial oxidation of the copper and tin which would entirely nullify the exact proportions originally taken.

Reducing agents, such as carbon, prevent oxidation, but the alloy takes up some car-

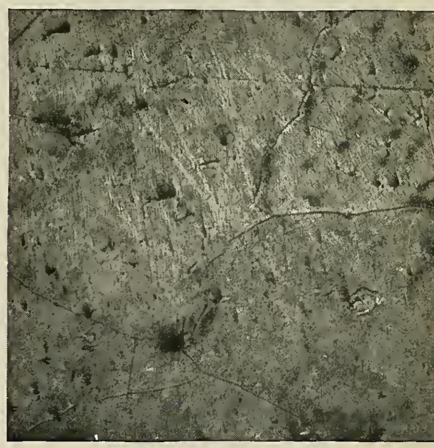


Figure 59 — Another specimen of conductivity copper. The black spots are polishing and etching pits, the large grains are due to annealing. Magnification 80X.

bon and the benefit of this addition may certainly be questioned. As the quantity taken up is variable, and generally unknown, we prefer to eliminate it altogether. The use of plumbago or clay crucibles is

also subject to criticism; the former may impart graphitic carbon and the latter iron oxide.

As an absolute safeguard from any possibility of oxidation and to eliminate the necessity for conjecture as to the effect of ever-changing quantities of carbon, the metals used for Crandall's Scientifically Tested Non-Zinc Alloy are melted in a pure silica crucible, in an enclosed electric furnace, under pure hydrogen gas. The hydrogen gas is generated simultaneously with the melting of the alloy, passing through a purifying train, and flowing over the surface of the metals throughout the melting. No heat is applied to the crucible until the air has been replaced by hydrogen.

Figure 60 shows the electric furnace used for melting, together with apparatus for generating and purifying hydrogen. A pure silica rod is used for stirring the alloy during its melting.

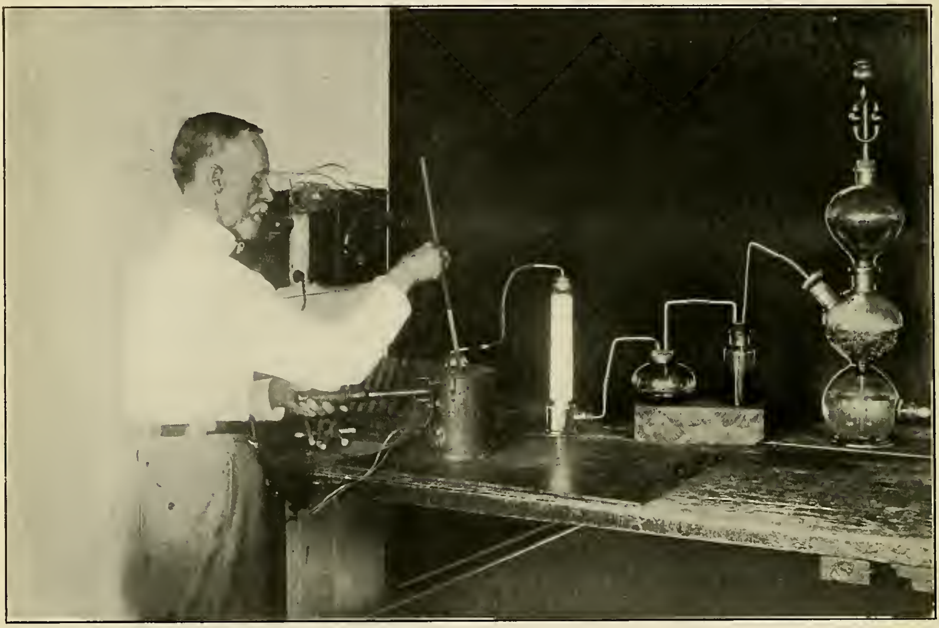


Figure 60 — Melting silver, copper, and tin in a closed electric furnace, under hydrogen gas.

Dental amalgam alloys are frequently made by placing silver and copper in the furnace first, adding the tin after these are melted. It requires a high degree of heat to melt the silver and copper alone and various alterations take place at this temperature which are not conducive to the formation of a homogeneous mass upon subsequent addition of the tin. In order to prevent oxidation, volatilization, and other complications, we alloy at as low an effective temperature as possible. The tin,

melting at 232° C., is introduced into the electric furnace first, and copper is added over a rising temperature gradient determined by pyrometric methods. Thereupon is formed the copper-tin solid solution which is converted into the correct ternary alloy by the addition of the silver. At no time is the melting point of copper or silver approached within several hundred degrees.

Throughout the melting of Crandall's Scientifically Tested Non-Zinc Alloy, metallographic control is maintained with respect to fusion period and maximum temperature; temperature gradient, as observed by means of the thermo-couple, with Siemens-Halske galvanometer and adjusted by a critical point rheostat; the rate of hydrogen flow, as affecting oxidation and reduction reactions; and homogeneity through mechanical agitation.

Casting

When the galvanometer records the casting temperature, Crandall's Scientifically Tested Non-Zinc Alloy is run into molds in an atmosphere of hydrogen and is cooled in a manner found to promote desirable physical qualities.

Filing

As the undue heat generated by friction in some cutting devices, produces undesirable physical changes in alloy, annealing it to an undetermined extent, Crandall's Scientifically Tested Non-Zinc Alloy is divided by hand files used in specially constructed machines. These are run so slowly that the generation of heat sufficient to cause physical changes in the alloy is avoided.

The filings produced by this method are rough and jagged in form, and offer a bright, clean surface to the attack of mercury. The size of the filings has been carefully determined to produce the maximum of strength in the undissolved integral unit, while permitting careful adaptation at the margins.

Annealing

To anneal a small amount of alloy, such an amount as a test tube would contain for instance, is a simple matter. It can be brought to the desired temperature immediately, maintained at that point for the desired period, and cooled at once.

To obtain this definite result with the comparatively large quantities of alloy which must be handled in a manufacturing laboratory involves problems which have been overcome by our method of annealing Crandall's Scientifically Tested Non-Zinc Alloy. The continued and indefinite annealing which would be produced by slowly bringing the alloy to the desired temperature and by slow cooling is avoided by a method which brings the whole amount of alloy immediately to the desired temperature. It is maintained at this point, without fluctuation to a higher or lower point, for a definite period of time, during which the alloy is kept constantly in motion. The return to room temperature is quickly made.

Formula

The balancing principle is generally conceded to be the correct one for combining the dental amalgam alloy metals in such proportions that shrinkage is eliminated and a minimum and controlled amount of expansion is obtained. This, of course, precludes the use of a formula, or we might say necessitates the determination of a formula for every lot of metals obtained.

Testing

After remelting, refining, and testing a lot of metals, a sample melt of fifty ounces

is made up into alloy and sent to Dr. Crandall for his test. This alloy is amalgamated by him and subjected to micro-micrometer tests. If it does not prove to be desirably balanced, but shows shrinkage or undue expansion, he corrects the percentage error which usually does not exceed 0.1 per cent.

When the alloy meets with his approval Dr. Crandall furnishes us with a certificate of his tests, showing the date of testing, setting or hardening period, expansion in twenty-five thousandths of an inch, and the parts of mercury which should be used to obtain this expansion.

The whole lot of silver is then made up in exactly the same proportions as the sample melt which has been tested and the information contained in the certificate given us by Dr. Crandall is copied on a certificate which is attached to every bottle of Crandall's Scientifically Tested Non-Zinc Alloy which is put up from the lot tested.

Research Laboratory Tests

Thermal analysis is an invaluable aid in research and enables us to verify or refute the claims made for alloys received by our laboratory. It has been found that assertions as to chemical composition, definite formula, annealing conditions, and other claims, are often entirely unsubstantiated. For instance, an alloy bearing the definite formula, "Ag_2SnCu," and "aged 20 minutes over water at 100° C.," shrunk upon amalgamation, and showed evidence of incorrect annealing. This alloy did not analyze for Ag_2SnCu, and a photomicrograph showed the eutectic structure of Figure 61, which was further verified by the long eutectic halt in the cooling curve obtained by thermal analysis.

In order to indicate the status of research upon ternary compounds the statement of the eminent metallographist, Dr. Rosenhain, is quoted:

"Unfortunately the difficulty of making a complete metallographic study of a system of alloys increases very rapidly with the number of component metals; for fifty determinations required for the elucidation of a binary system of alloys, 1250 would be required for a system of three metals, while no attempt at the complete systematic study of a quaternary system (of four metals) has yet been made, but for corresponding completeness over 30,000 determinations would be needed. In the case of a ternary system (of three metals) it is still possible to employ a graphic representation; the concentration of a system of ternary alloys may be plotted in the form of an equilateral triangle, each corner representing one of the pure component metals; each side of the triangle then represents one of the three limiting binary systems, while the position of any point within the triangle represents the com-

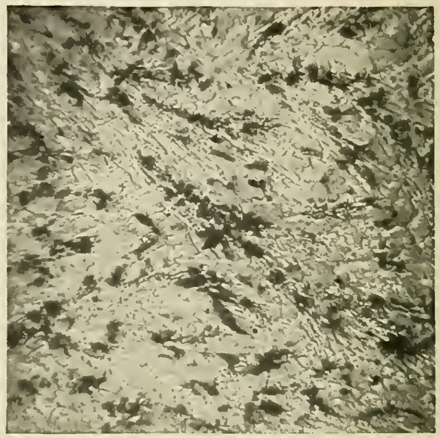


Figure 61 — Eutectic structure of alloy represented as Ag^2SnCu.

position of an alloy of a ternary system, on the principle of trilinear co-ordinates. Upon this equilateral triangle as a base, the 'equilibrium diagram' can be erected as a three dimensional model, ordinates representing temperature being erected upon each point of the area of the triangle. A few such equilibrium models of ternary systems have been more or less completely determined, but the field is still largely unexplored. It is interesting to note however, that *no tri-metallic compound has yet been discovered.*"

The location of Crandall's Scientifically Tested Non-Zinc Alloy upon the ternary diagram is shown in Figure 62.

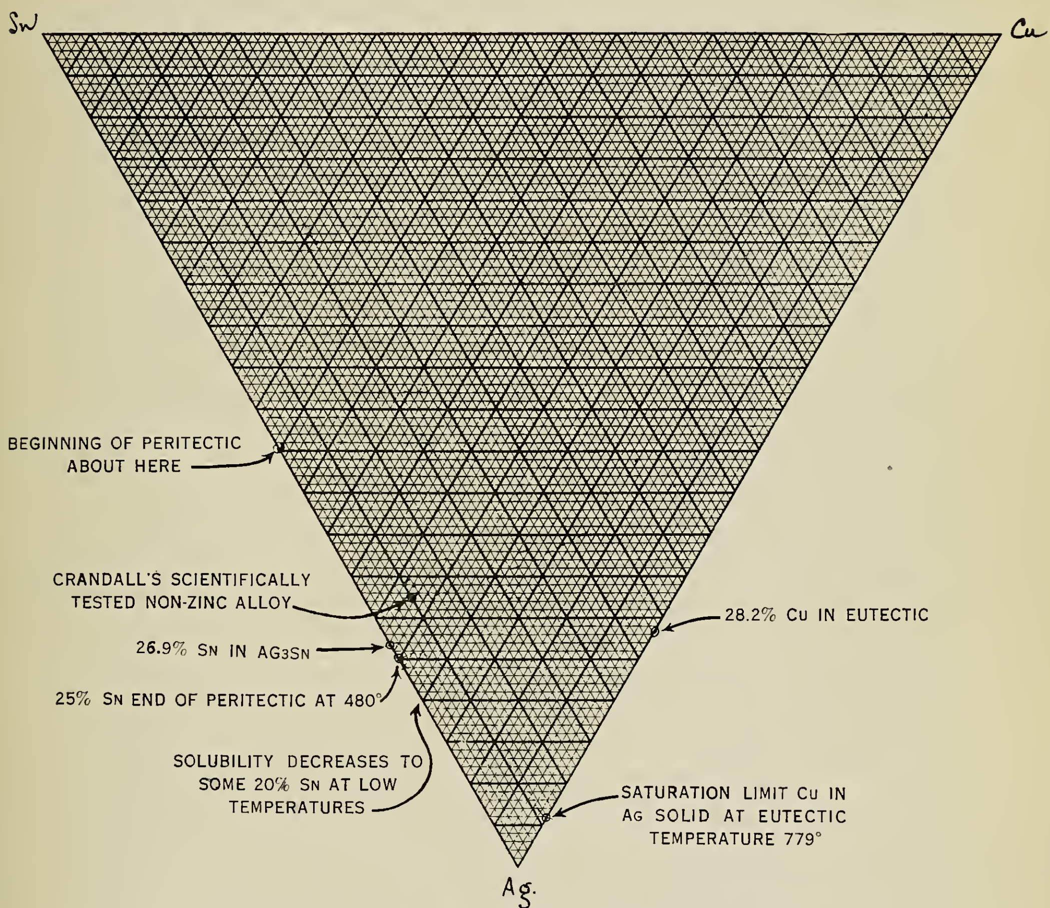


Figure 62 — Ternary diagram showing the location of Crandall's Scientifically Tested Non-Zinc Alloy.

Instruments, Materials and Appliances

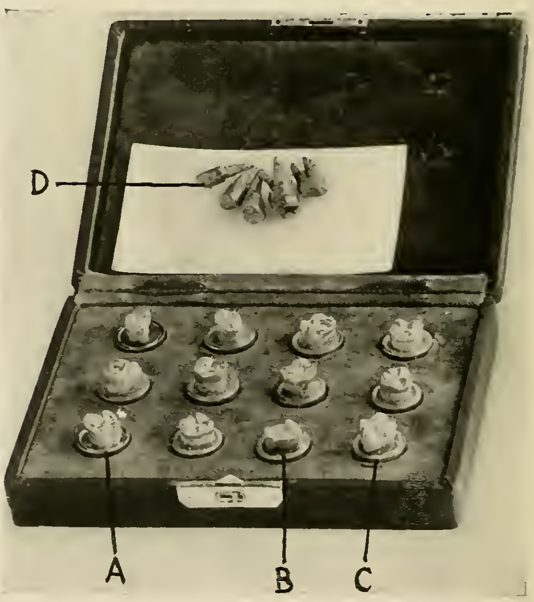
used in the

Crandall Method of Amalgam Restoration

IN the following pages instruments, materials, and appliances which have been developed by Dr. Crandall or have been designed to meet his requirements are shown. To these have been added amalgam condensing instruments designed by Dr. Prime and amalgam carving instruments designed by Dr. Frahm.

An equipment may be selected from these pages which will fully meet the demands of a standardized amalgam technic and, in all cases, the Clev-Dent standard of quality has been maintained.

Crandall Demonstrating Case



THIS case has been devised as an aid in explaining to patients the desirability of amalgam restorations as compared to inferior work. It is a small leather case, velvet lined, with space for twelve steel rings which are used to hold teeth with various forms of cavity preparation, amalgam restorations, and other features of the work which it is desired to bring to the patient's attention.

The teeth are not supplied with the case, but may be prepared by each dentist with a view to meeting the particular needs of his practice.

The case, shown here, contains restorations which include nearly all of the forms usually encountered in practice, including several restorations of the entire crown, such as A. At B is shown the cavity preparation for an amalgam crown, at C a cavity preparation in the medio-occlusal surfaces of an upper molar. At D are five extracted teeth which have been lost because of the poor adaptation of gold crowns.

Crandall's Scientifically Tested Non-Zinc Alloy

Authoritative information regarding the effect of zinc and overaging on dental alloys has long been accessible, but dentists have failed to demand an alloy made to conform to the highest standards and have even been content with unbalanced alloys because of their plastic, easy-working qualities. The manufacturer has been content to deal in glittering generalities in describing his alloys, avoiding definite facts and figures, specifications, and tests.

Contrary to this plan, investigation of all methods of alloy making has preceded the manufacture of Crandall's Scientifically Tested Non-Zinc Alloy and fullest advantage has been taken of all authoritative information obtainable. Much of original research has confirmed or rejected various methods and has evolved new refinements of the process.

In addition to chemical and metallographic tests of materials and micrometer tests of the finished product made in our own laboratories, every lot of Crandall's Scientifically Tested Non-Zinc Alloy is tested by Dr. Crandall.

Crandall's Scientifically Tested Non-Zinc Alloy

CERTIFICATE OF TEST

Spencer, Iowa 3-21 1914

This certifies that I have tested Lot No. B101 manufactured 3-21-14 of Crandall's Scientifically Tested Non-Zinc Alloy and find the following results:

With 10 parts alloy 11 parts mercury should be used. Expansion is 7 /25000 of an inch.

Setting Med. W. Crandall

CERTIFICATE OF TEST

Spencer, Iowa April 11 1914

This certifies that I have tested Lot No. B107 manufactured 4-7-14 of Crandall's Scientifically Tested Non-Zinc Alloy and find the following results:

With 10 parts alloy 11 parts mercury should be used. Expansion is 5½ /25000 of an inch.

Setting Medium W. Crandall

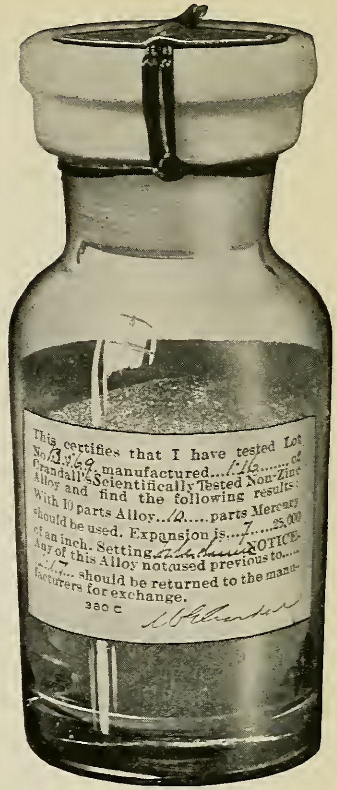
Dr. Crandall certifies to his test of every lot of the alloy, furnishing us with a certificate, showing the setting qualities, expansion in twenty-five thousandths of an inch, and the parts of mercury to be used to obtain this amount of expansion. Facsimiles of two of these certificates are shown on this page. The date of manufacture is also shown on each certificate. The information contained in this certificate is transferred to the label of every bottle of Crandall's Scientifically Tested Non-Zinc Alloy put up from the lot tested.

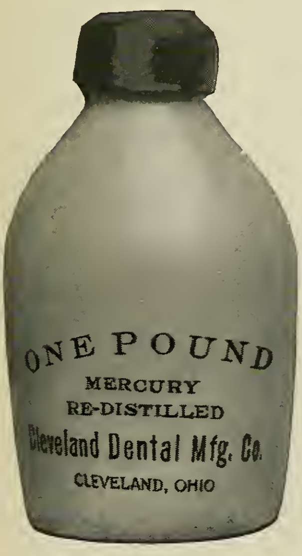
Crandall's Scientifically Tested Non-Zinc Alloy

In addition to the blue label which serves as a ready means of identification of Crandall's Scientifically Tested Non-Zinc Alloy, every bottle of this alloy bears on its reverse side a certificate label which contains the information certified to by Dr. Crandall in his test of the alloy.

It would be quite possible for a dentist to purchase a quantity of alloy and after retaining it for a long time, to return it to his dealer who would, not knowing its age, sell it again. The user of Crandall's Scientifically Tested Non-Zinc Alloy is fully protected from the possibility of using an overaged alloy by the date of manufacture which appears on every package, and from loss of alloy overaged in his own hands, by our offer to exchange, without charge, all alloy on hand one year from the date of its manufacture.

Dr. Crandall's Certificate of the exact amount of expansion and the parts of mercury to be used with the particular lot of alloy tested places in the dentist's hands information which is invaluable in obtaining the definite and dependable results which he should expect from a correct amalgam technic.



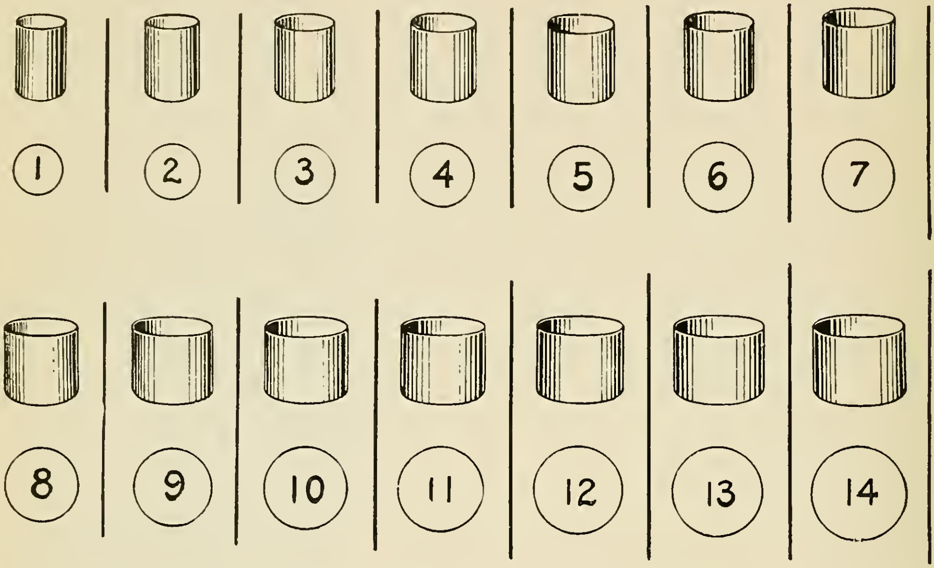


Clev-Dent Redistilled Mercury

A CHEMICALLY pure mercury which is guaranteed not to contain foreign metals which might disturb the proportions of an accurately balanced alloy.

This is put up in jugs containing one pound, as shown in the illustration, also in bottles and cones, containing one-quarter pound each.

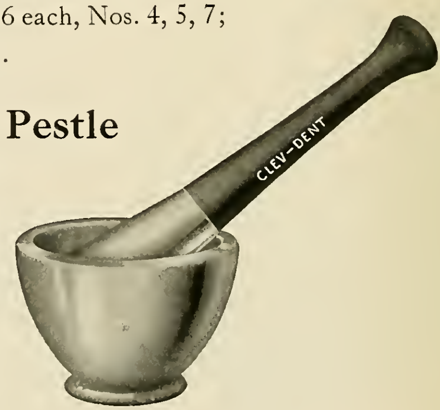
Crandall Seamless Copper Matrix Bands



An assortment of seamless copper bands of suitable size for use as matrices in making full or partial amalgam crowns as described by Dr. Crandall on page 16. The illustration shows the actual circumference of the bands and the line at the right shows the length when cut. The height of bands is 8 mm.

These bands are put up in boxes containing twenty-five bands of one size and in compartment boxes containing one hundred bands in the following assortment: 5 each, Nos. 1, 2, 3, 6, 13, 14; 6 each, Nos. 4, 5, 7; 8 each, Nos. 8, 12; 12 each, Nos. 9, 10, 11.

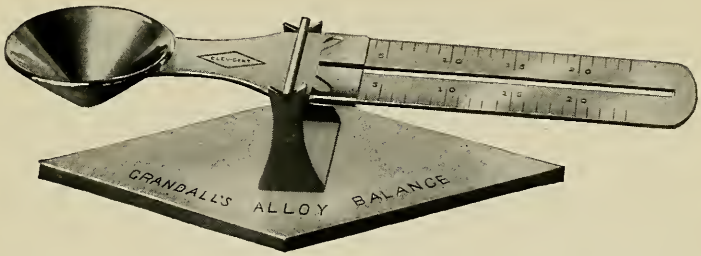
Wedgwood Mortar and Pestle



DR. CRANDALL recommends a pestle of sufficient size and correct shape to touch all points in the mortar for triturating alloy. This mortar and pestle have been carefully designed to meet his requirements. Another view is shown on page 39, Figure 40.

Crandall Alloy Balance

Patented—June 6, 1916



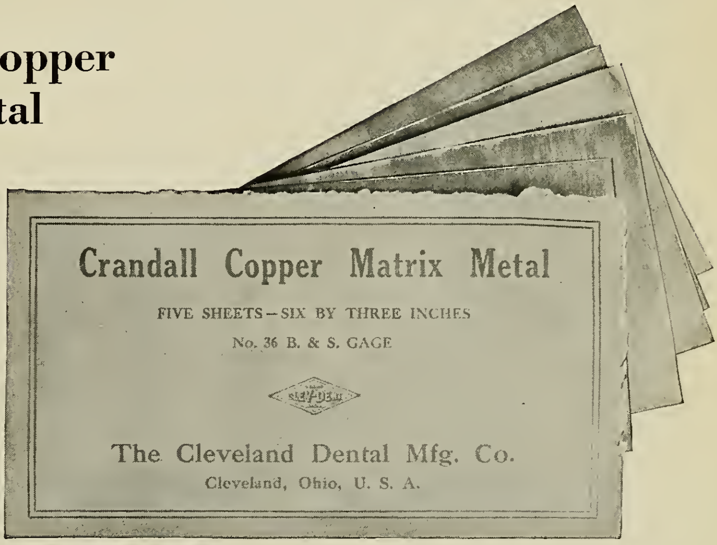
A SMALL well made balance, indicating weight in parts. Its accuracy is quite sufficient for determining proportions of mercury and alloy so that the sloppy excess of mercury, which is likely to disturb the balance of the metals when expressed, is avoided. Accurate judgment of the amount of amalgam required for fillings of various sizes, is soon acquired with the help of this balance and a decided economy in the use of alloy is the result.

The balance is most conveniently used by setting one of the sliding weights on the arm at the number of parts of alloy required and slowly sifting alloy from the bottle into the pan until it is balanced. After the alloy is poured into the mortar, without disturbing the first weight, set the second weight for the additional parts of mercury required and pour in mercury to balance.

Crandall Copper Matrix Metal

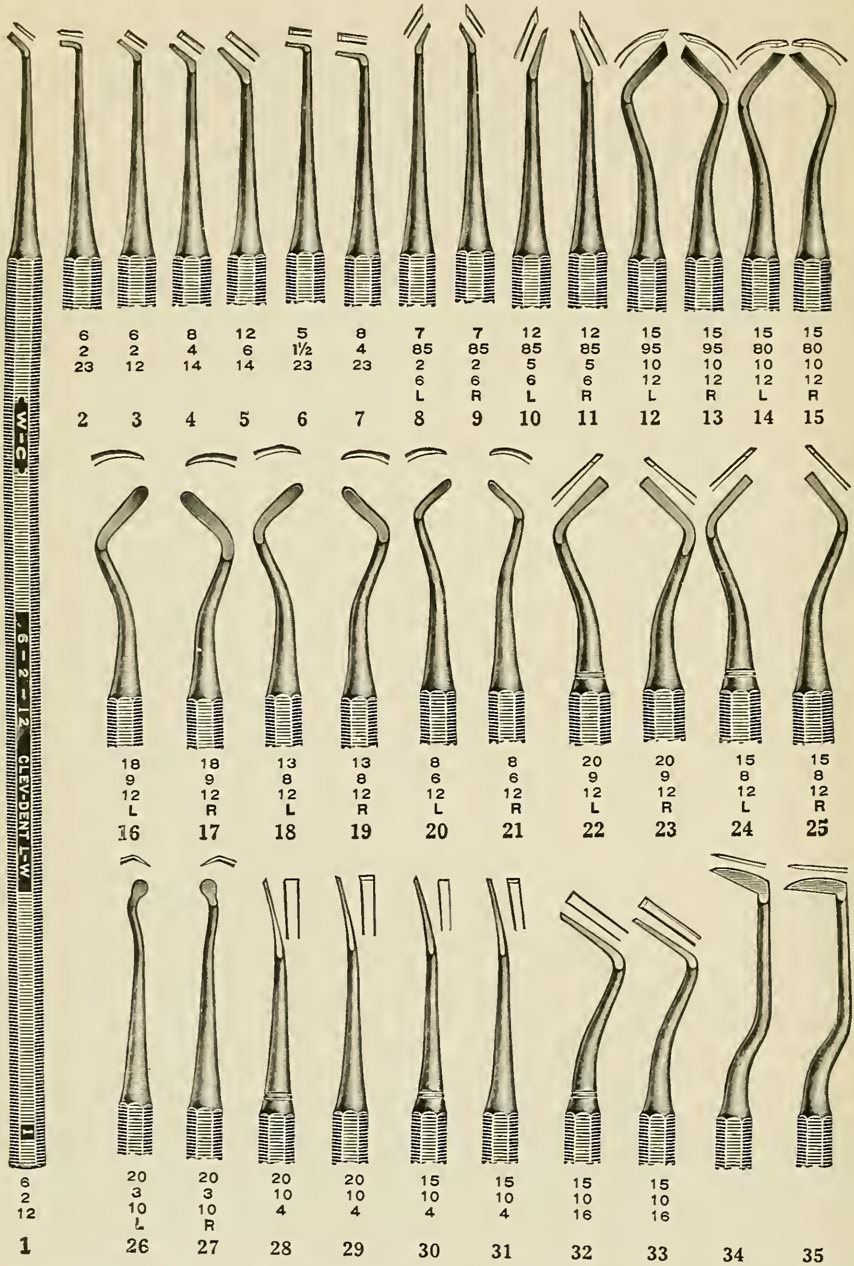
For making the tied copper matrices described by Dr. Crandall on pages 13 to 15.

Each package contains five sheets of 36 ga. copper, six by three inches.



Woodbury-Crandall Instruments for Cavity Preparation

Design Patent Applied for



Woodbury-Crandall Instruments for Cavity Preparation

THE forms which make up this new set of instruments for cavity preparation have been carefully chosen and adapted by Dr. Charles E. Woodbury and Dr. Walter G. Crandall from some of the best known and generally approved sets of cutting instruments. Their form has been modified somewhat and a radical change has been made by shortening the neck, bringing the handle much nearer the cutting edge of the instrument and affording a very firm finger grasp with increased leverage and control. The diameter of the handles of the instruments varies, being carefully adjusted to balance the width of the cutting edge. The instruments are practically universal in their application and include all the necessary forms for the preparation of cavities on any surface of the teeth.

For the most efficient use of these instruments, we suggest the duplication of those forms oftenest in use, so that an instrument need never be used after it has been sufficiently dulled to cause pain. An economical and time saving arrangement may be made with us for sharpening these and all other hand operating instruments for a fixed sum per year.

Nos. 1 and 2 are hatchets for forming angles in the anterior teeth.

Nos. 3, 4, and 5 are contra angle hoes, and 6 and 7 are right angle hoes, instruments of the widest application in cavity formation.

Nos. 8, 9, 10, and 11 are right and left angle forming instruments designed especially for carrying out the sharp line angles in cavities in the anterior teeth.

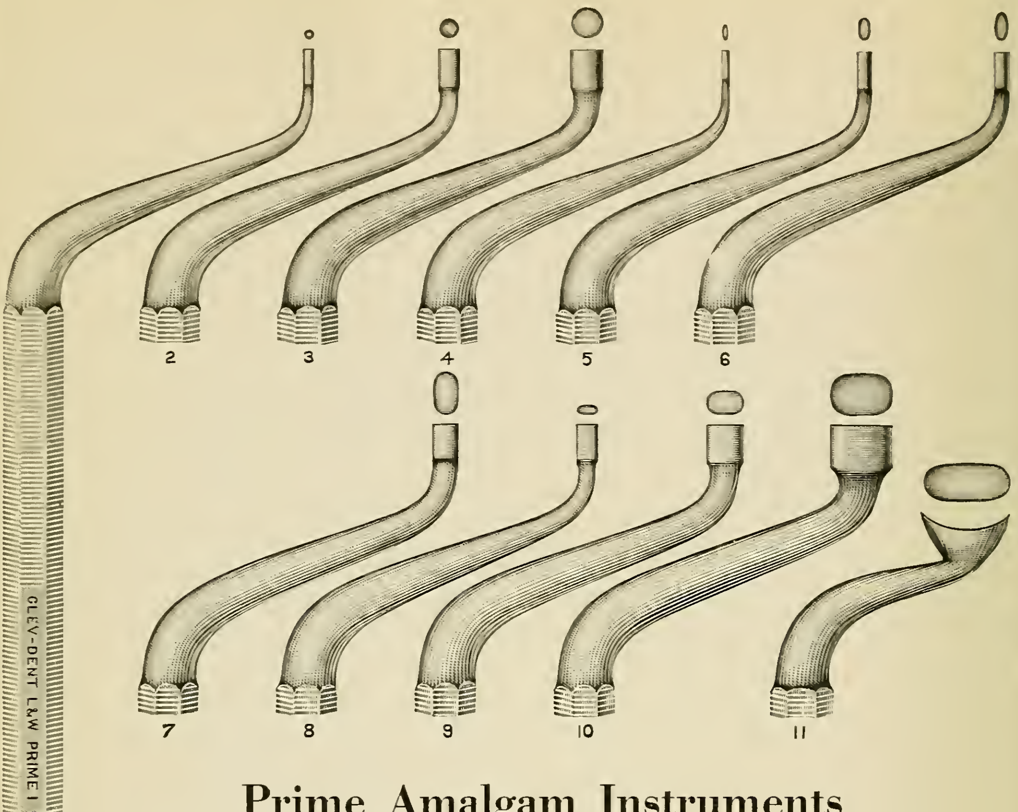
Nos. 12, 13, 14, and 15 are right and left, mesial and distal gingival margin trimmers.

Nos. 16, 17, 18, 19, 20, 21, 26, and 27 are right and left spoon excavators.

Nos. 22, 23, 24, and 25 are right and left enamel hatchets for breaking down enamel and shaping cavity walls in bicuspids and molars, one of each pair is marked with a ring to distinguish the direction of cut without examination of the cutting edge. Nos. 28, 29, 30, and 31 are front and back cut enamel cutting chisels. One of each pair is marked with a ring so that those which cut on the back may be distinguished from those which cut on the face, without examination of the cutting edge. These enamel instruments have a special temper, differing from that of the other instruments of the set. On account of their special hardness, they not only are better suited for cutting enamel but will hold their edge longer.

Nos. 32 and 33 are special instruments for cutting mesially and distally in molar cavities which are difficult of access.

Nos. 34 and 35 are finishing knives designed for finding and removing overlaps along the gingival margins of fillings on the proximal surfaces.

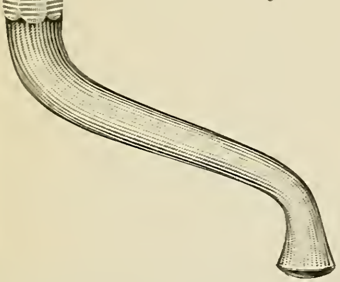


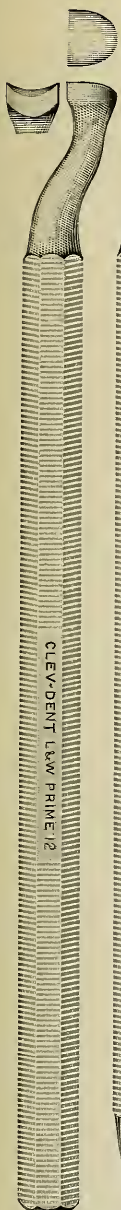
Prime Amalgam Instruments

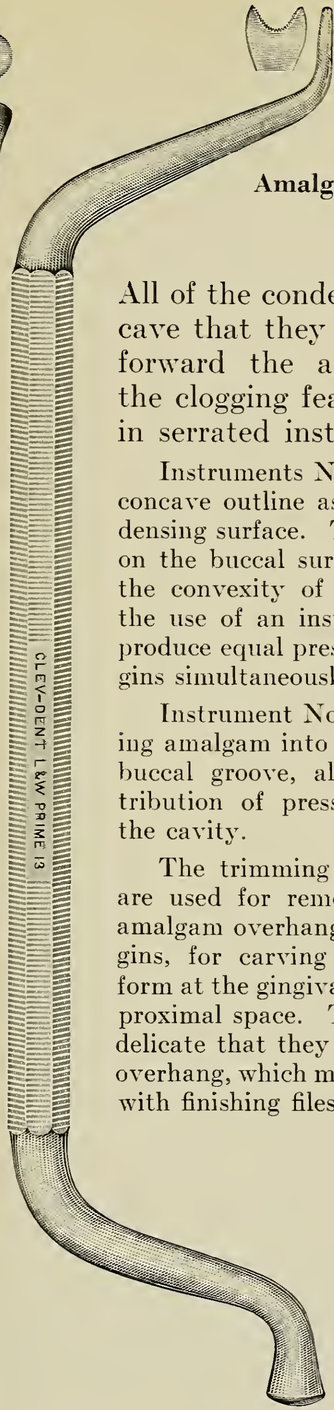
Patent Applied for

With the advances recently made in the development of amalgam technic, the necessity for instruments which may be used with the mallet to carry pressure or force directly into the angles of the cavity has become apparent. Dr. J. M. Prime has met this need by designing the set of amalgam condensing instruments shown here.

These instruments are necessarily heavy in construction, to avoid any tendency to spring under pressure. The bayonet is sufficiently long to permit of access to the distal portion of posterior teeth, and the opposite end of the instrument has a corresponding offset so that force applied to the end of the handle with the mallet will be in direct line with the condensing point.







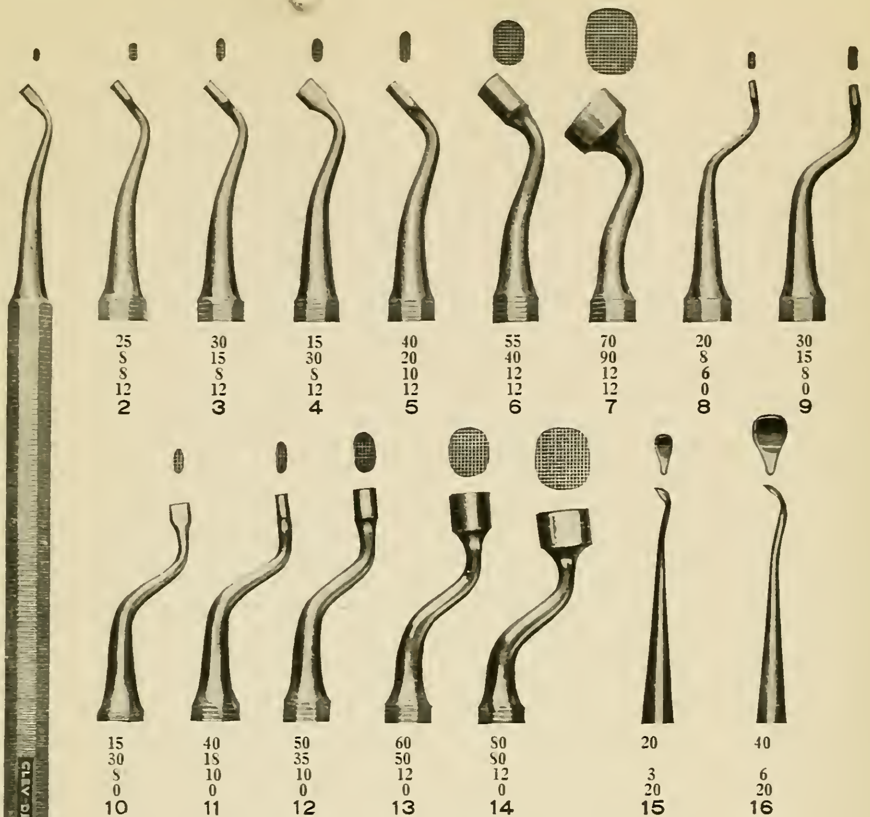
Prime Amalgam Instruments

All of the condensing points are concave that they may grasp and force forward the amalgam, eliminating the clogging feature so inconvenient in serrated instruments.

Instruments No. 11 and No. 12 have a concave outline as well as a concave condensing surface. This adapts them for use on the buccal surface of the teeth, where the convexity of the surface necessitates the use of an instrument of this form to produce equal pressure over all of the margins simultaneously.

Instrument No. 13 is used for condensing amalgam into cavities occurring at the buccal groove, also providing equal distribution of pressure into the angles of the cavity.

The trimming knives Nos. 14 and 15 are used for removing small particles of amalgam overhanging at the gingival margins, for carving the correct anatomical form at the gingival and restoring the interproximal space. These instruments are so delicate that they will detect a very slight overhang, which may afterward be removed with finishing files or strips.



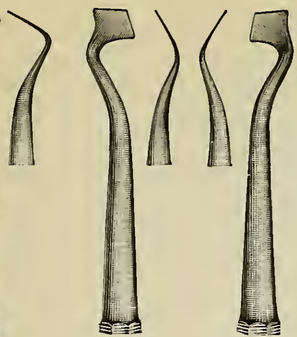
Crandall Amalgam Instruments

THESE instruments have been designed by Dr. Crandall to fit into the proximal and occlusal portions of such cavities as are usually made in bicuspid and molar teeth for amalgam fillings. As will be noted from the illustration, they have shortened shanks bringing the working point of the instrument closer to the grasp which controls it and affording great leverage and very accurate control. When used as pluggers to carry a mass of amalgam and condense it under heavy hand pressure, supplemented by mallet force, they will produce the greatest possible density and strength in the filling.

Nos. 1 to 7 are for cavities in the inferior teeth which are inaccessible to the bayonet shaped instruments, Nos. 8 to 14.

Nos. 7 and 14 are especially valuable as their size allows them to condense a mass of amalgam over all the margins of the cavity, simultaneously, thus avoiding the movement away from some portions of the margins which is always produced by the use of small pluggers.

Nos. 15 and 16 are amalgam formers for reducing the excess of amalgam to the cavity margins and for preliminary carving in the restoration of the natural tooth form.



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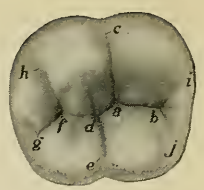


Frahm Carving Instruments

THE occlusal surface of amalgam restorations is easily and correctly carved with these instruments so that normal masticatory form and function are restored. There are four sets of the instruments, each made up of a straight instrument, a right, and a left. The four sets differ from one another in the cutting angle of the blades, which is 75°, 90,° 105°, or 120°. These angles will take care of all the varieties of fissure formations found in the human teeth. The set illustrated has cutting blades at an angle of 105°. The other angles are shown, in comparison with this, in the drawing at their right.

Dr. F. W. Frahm, who supplied the patterns for these instruments, has also furnished us with the following technic for their use in the mouth or upon models:

"In the case of the occlusal surface of an inferior first molar involving all the fissures: Place the blade of the straight instrument (No. 1) at the point 'a' where the buccal fissure joins the central fissure, embedding the blade in the wax or amalgam until the blades touch the margin of the cavity. Draw the instrument forward, allowing both sides of the blade to cut to their full depth, until the medio-occlusal marginal pit 'b' is reached. Then using either the right or the left instrument, according to the tooth, place it in the fossa end of the buccal fissure 'a,' pass it to the buccal side, following the course of this fissure, releasing the pressure as 'c' is neared. Then, using the straight instrument, cut from 'a' to 'd' with a push cut; from this point, push the instrument distally to the juncture of the disto-buccal and distal fissures 'f.' Select the proper right or left instrument, as indicated, place it at 'd' and draw lingually to make that fissure, then with the same instrument placed at 'b' draw to 'i' and 'j' to finish the medio-marginal pit. Then place it at 'f' and draw to 'g' and 'h.'

"When passing a triangular ridge the pressure should always be released somewhat, but always start in a pit and end in another with a steady clean cut. In case of lingual or buccal fissures the pressure should be released when the coronal ridge is neared or crossed.

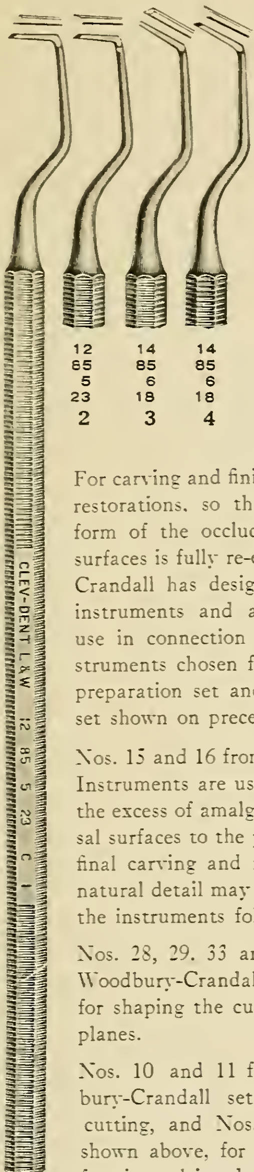
"The angle of the set of instruments to be used on the tooth should be selected to conform to the fissures found in other teeth of the same mouth.

"Supplemental fissures may be made by placing one edge of the blade on the material and gouging slightly until they are the desired depth.

"The cutting should be done with a firm hand and clean cut. The use of the instruments is only limited by the anatomical variation of the tooth."

Crandall Carving Instruments

Design Patent Applied For

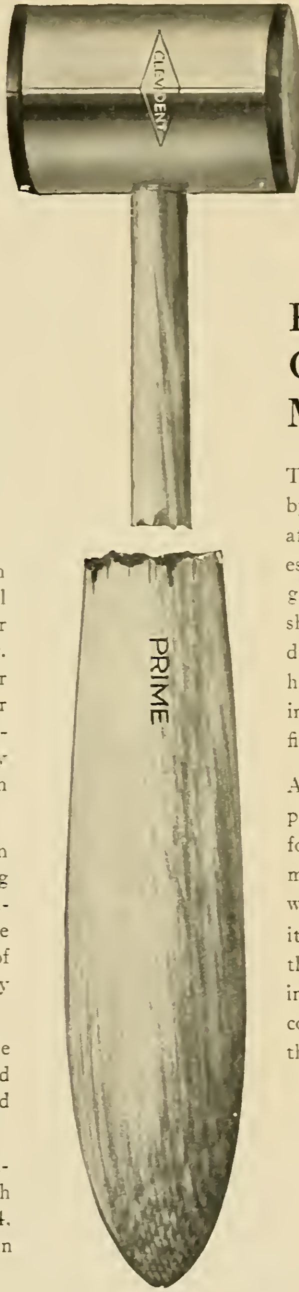


For carving and finishing amalgam restorations, so that the natural form of the occluding and other surfaces is fully re-established. Dr. Crandall has designed these four instruments and advocates their use in connection with other instruments chosen from the cavity preparation set and the amalgam set shown on preceding pages.

Nos. 15 and 16 from the Amalgam Instruments are used for reducing the excess of amalgam upon occlusal surfaces to the point where the final carving and reproduction of natural detail may be taken up by the instruments following.

Nos. 28, 29, 33 and 34 from the Woodbury-Crandall set are used for shaping the cusp surfaces and planes.

Nos. 10 and 11 from the Woodbury-Crandall set are for push cutting, and Nos. 1, 2, 3 and 4, shown above, for pull cutting, in forming sulci and pits.



Prime Condensing Mallet

This mallet was designed by Dr. J. M. Prime for affording the pressure necessary to condense amalgam. The illustration shows the actual length and diameter of the head. The hickory handle is nine inches long, the head weighs five ounces.

A brass tube, heavily nickel-plated and filled with lead forms the head of this mallet. The ends are faced with leather, inset so that it covers the entire face of the mallet and prevents the instrument from coming in contact, accidentally, with the metal edge.

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